

A NUMERICAL STUDY OF CONVECTIVE HEAT TRANSFER IN STORED RESPIRING AGRICULTURAL PRODUCE

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BY

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30001002329433 Li, Patrick Xiao-ping A numerical study of convective heat transfer in stored respiring To my parents and my wife.

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ABSTRACT

A mathematical model of natural convection in three-dimensional enclosures containing respiring fruits or vegetables is presented. The agricultural produce is treated as a porous media exhibiting transversely orthotropic permeability in which local temperature-dependent respiration heat generation occurs.

In the numerical investigations conducted, both adiabatic and isothermal boundary conditions are considered for the cooling and storage process. The influence of container size, respiration rate and permeability on natural convection is discussed. Numerical experimental results for temperature distribution, velocity distribution, true transient cooling and storage process are presented.

It was found that the style of packaging of the agricultural produce and the size of container were likely to have significant effects on the storage characteristics.

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NOMENCLATURE

Notation

A = surface area of representative elementary volume (r.e.v.), m^2

C = specific heat of solid, $J/kg\cdot K$

 C_p = specific heat of fluid at constant pressure, J/kg·K

 D_a = Darcy Number

 D_{eff} = effective diameter of fruit and vegetables

g = gravitational acceleration, m/s²

 \vec{G} = gravity force, N

 G_x , G_y , G_z = x, y and z, components of gravity force

h = grid distance

 H_{min} = minimum grid distance

 k_{eff} = effective thermal conductivity of porous medium, kW/m·K

L = length of the (channels), pipes, m

n = number of channels per unit cross-sectional area, $1/m^2$

N = number of channels in a cross-sectional area

Nu = Nusselt number

 $Nu_{average}$ = Average Nusselt number on side walls or top or bottom of the

container

 \vec{n} = normal unit vector

P = pressure, N/m²

= volume flow rate, m³/s Q = internal heat source in energy equation, kW/m³ Q_{heat} = flow rate in a single pipe, m³/s Q_i Q_{10} = temperature quotient of respiration of fruit and vegetables r = effective radius, m Ra = Rayleigh number R_c = defined in equation (3.97a) R_I , R_2 = respiration rates, mg Co₂/kg·h = cross-sectional area, m² S = specific surface 1/m S_{ν} = time, s t = temperatures, °C t_1 , t_2 = iterative time step for solving vector potential Δt_{inner} = iterative time step for main loop Δt_{main} = Temperature, K \boldsymbol{T} = x, y and z components of velocity u, v, w \vec{V}_f = intrinsic velocity, m/s \hat{V}_f = volume of fluid inside a r.e.v., m³

 \vec{V}_p = seepage velocity, m/s

 \hat{V}_{p} = volume of r.e.v., m³

x, y, z = coordinate

 x_0, y_0, z_0 = rectangular enclosure dimensions, m

Greek Symbols

= porosity ε = density, kg/m³ ρ = dynamic viscosity, kg/m·s μ = effective viscosity, kg/m·s $\tilde{\mu}$ = permeability tensor K = convective heat transfer at boundaries, kW/m².°C α_n = angles between gravity direction and x, y and z coordinate axis α, β, γ = vector potential, m²/s = scalar potential, m²/s = water content in fruits or vegetable, per cent % = reference air density at 273K, kg/m³ ρ_{o} = thermal coefficient of volume expansion, 1/K β_o = permeability, m² κ = dimensionless temperature θ = false transient coefficient of vector potential α_{ψ} = intermediate variable for Samarskii-Andreyev Implicit Alternating ω Direction Method = constant, 0-1 δ

= iteration time step length

Subscripts

 Δt

p =porous media

f = fluid

air = air

s = solid

x, i = x direction or x component

y, j = y direction or y component

z, k = z direction or z component

h = hot temperature

c = cold temperature

start = initial temperature

Superscript

= non-dimensional mark

CHAPTER 1

INTRODUCTION

1.1 Background

In modern society the distribution and marketing of fresh agricultural and horticultural produce is a vitally important activity and the endeavour put into it is reflected in the general standard of living of the community. Distributing and marketing of fresh fruits and vegetables encompasses storage, packaging, handling and transportation. The distribution chain for fresh produce is greatly dependent on good storage and preservation methods, which in turn, are based upon reliable knowledge of the physical and physiological processes of individual commodities. Storage conditions are not only important in long-term cold storage, but also in transport vehicles, interim storage before packaging or retail outlet storage. Regardless of the manner in which produce is stored, the principal aim of any storage operation is to extend the useful life of a commodity by preventing significant deterioration in its quality.

Unless suitable storage and preservation techniques are available to prolong shelf life, most fruits and vegetables would have to be consumed within a relatively short period of time. Advances in agriculture have generally resulted in higher yields of fruit and vegetable crops, however if seasonally harvested crops are not able to be utilised over a period considerably longer than their growing season, higher yields do not necessarily lead to

increased benefits - storage is indispensable for prolonging the availability of fresh produce to consumers, extending the food processing season, damping fluctuations in supply and minimising market prices.

Fresh commodities are often highly perishable; Salunkhe (1974) estimates that 25% to 50% of all produce harvested is not consumed because of spoilage during storage or distribution. Billions of dollars are lost annually by growers, shippers, warehouse owners, processors and retailers around the world. Essentially, this is because fruits and vegetables are living organisms even after they are detached from the plant. The life processes require energy and the produce has to supply this from its own reserves and their continued respiration uses up oxygen and gives off carbon dioxide and heat. Produce sustains a continuous weight loss and constantly undergoes changes in chemical composition which may adversely affect its quality. Also this process of deterioration renders the produce more susceptible to microbial attack. The other important process common to produce in storage is water vapour loss or transpiration. Most fruits and vegetables have a water content of 75%-90%. Every percentage point of produce weigh loss may add up to millions of dollars worth of produce over a season in a large-scale distribution system.

The environmental factors affecting transpiration rates are temperature, relative humidity, air velocity and barometric pressure in the storage room or inside the storage container. High relative humidity can reduce the water loss rate but may enhance accelerated decay. To slow the deterioration, a low temperature is necessary to reduce the respiration rate. The quality of storage produce is often critically influenced by storage conditions. Table 1.1, after Hardenburg (1986), shows the recommended temperature and the suggested

storage time for a variety of fruits and vegetables.

Table 1.1 Recommended temperature and approximate storage life of fresh fruits and vegetables in commercial storage (Hardenburg 1986)

| Commodity | Temperature ⁰ C | Approximate storage life |
|------------------------|----------------------------|--------------------------|
| Apple | -1-4 | 1-12 months |
| Apricots | -0.5-0 | 1-3 weeks |
| Kiwifruit | -0.5-0 | 3-5 months |
| Oranges (Fla. & Texas) | 0-1 | 8-12 weeks |
| Pears | -1.5 to -0.5 | 2-7 months |
| Asparagus | 0-2 | 2-3 weeks |
| Beans (green) | 4-7 | 7-10 days |
| Broccoli | 0 | 10-14 days |
| Brussels sprouts | 0 | 3-5 weeks |
| Cabbage (Chinese) | 0 | 2-3 months |
| Carrots (mature) | 0 | 7-9 months |
| Celery | 0 | 2-3 months |
| Corn (sweet) | 0 | 5-8 days |

Local differences in temperature within the storage rooms or in storage containers will cause different local rates of deterioration in different places. Thus non-uniform conditions will affect the overall quality of the stored produce. Sometimes unacceptable deterioration in certain areas leads to the storage having to be suspended immediately to prevent further loss or disease spread. Therefore a uniform temperature distribution in storage rooms and containers is considered highly desirable. Uniform temperature distribution is also important for fruit ripening, for example, bananas ripening prior to selling and potatoes prior to certain food processing operations. Certain commodities, notably onions and potatoes, are stored at ambient temperature rather than in cool or refrigerated storage. Optimal uniform temperature is maintained to avoid decay or chill injury. With respiration heat generated inside a closed container, there is clearly a temperature difference between the inside of the container and the environment. The density differences in air due to temperature differences will produce a buoyancy force and natural convection will occur in the container. The warm air will rise in the central area toward the top; it will then be cooled by the walls and move down near the walls to the bottom.

Natural convection occurs in some pre-cooling processes also. Normally the field heat in the produce when harvested is removed by some kind of pre-cooling operation as quickly as possible. Hydro-cooling, vacuum cooling and cold room cooling are examples of different pre-cooling processes. For some commodities which do not require, or tolerate rapid cooling to a low temperature, or those with a package not suitable for hydro-cooling, cold storage room cooling is usually the method chosen. In this case, the container or box can be considered as a relatively impervious to air flow around it and the heat transfer is mainly the result of natural convection inside the box. Forced or mixed convection may

take place in some fast efficient pre-cooling situations. Some commodities which do not tolerate rapid air velocity, which causes excessive water loss, can benefit from natural convective pre-cooling.

How natural convection affects the temperature distribution inside stored packaged produce, and how the respiration heat contributes to the temperature accumulation are processes about which a deeper understanding is sought in this study. In order to improve storage techniques we have to recognise how stored commodities respond to the external environment and gain insight into the processes that govern the rate of heat and mass transfer inside storage facilities.

1.2 Literature Review

Considerable research has been carried out in the area of cold storage of agricultural and horticultural produce, but until recently, little attention has been directed toward to the influence of natural convection on the heat and mass transfer processes taking place during the cooling of produce. Moon (1987) performed a study on mixed convective hear transfer from horizontal cylinders in order to predict post harvest cooling of cylindrically shaped agricultural produce. Woods (1990) discussed at some length the physical phenomena responsible for moisture loss from commodities with high moisture contents.

Computer modelling of the thermal balance within a bin of apples was carried out to predict temperature distributions and air pattern movements by Robinson (1988). Numerical

and experimental analysis of mixed convection around a sphere which was aimed at understanding the heat transfer from a single fruit was carried out by Johnson (1988) and Tang and Johnson (1992).

Interest in natural convective fluid flow and heat transfer in porous media has been influenced by a broad range of applications which include solidification of castings, acquifiers, geothermal systems, insulating materials and oil field production. Another application which has attracted a good deal of attention is the storage of nuclear waste materials, this differs from the previously mentioned examples in that it has been modelled as a natural convective process in a porous media with internal heat generation. It is proposed in this study, that an essentially analogous process takes place within impervious containers used to store agricultural produce, where convective heating or cooling of the contents occurs in conjunction with internal heat generated by the respiring produce.

In the design of cool storage facilities it has been the custom to neglect the affects of natural convection in favour of conductive heat transport when determining temperature distributions and cooling rates in closed containers. However, during cooling (or heating) natural convection must occur within closed containers if temperature gradients exist between the container walls and the produce. During the transient cooling of stored commodities that do not generate respiratory heat, natural convection processes will cease completely when steady state conditions are reached. On the other hand, for those commodities that do generate internal heat, natural convection continues, even after steady state has been achieved.

Repeated transient heating and cooling is the kind of process that might still carelessly be ignored by present day design engineers, but the lesson we learn from history is that transient heat transfer can be of overwhelming importance. Designers of food or produce storage enclosures should be well aware that such systems require comparatively little energy to keep products cool at steady state conditions. The consumption of energy to bring stored products to a low temperature constitutes the principal cost of operating such systems. Transient heat and mass transfer processes are a dominant concern in the design of storage units. Although there has been a longstanding interest in the storage of agricultural and horticultural produce, few researchers have investigated the influence in transient heat and mass transfer phenomena of natural convection in combination with respiration.

A number of studies concerned with natural convection in porous media with internal heat generation have been carried out. Gasser and Kazimi (1976) applied the method of linear stability of small disturbances to calculate the critical internal and external Rayleigh numbers that identify the onset of natural convection in porous media with internal heat generation. Buretta and Berman (1976) conducted experiments on a liquid saturated porous layer heated from below or heated from distributed sources. An experimentally obtained slope of the Nusselt versus Rayleigh number relationship was presented but details of temperature and velocity fields were not given. Experimental results have been presented by Hardee and Nilson (1977); Rhee, Dhir and Catton (1978) and Kulacki and Freeman (1979). Analytical extensions to the problem were made by Tveitereid (1977) who obtained a steady state solution in the form of hexagonal cells and two-dimensional rolls for natural convection in a horizontal porous layer heated from within.

Beukema et al (1980, 1983) reported a three-dimensional study of natural convection in a confined porous medium with internal heat generation to model the process of storing fruit and vegetables. Both numerical and experimental results were presented and discussed. In their study, they assumed that heat generation was uniformly distributed in the porous medium. The heating rate was assumed constant for each numerical experiment and results for a number of different values of constant heating rate were given. Darcy's law was applied with the permeability of the porous medium so constructed as to ensure isotropy. To solve the governing equations the Alternative Direction Implicit Procedure, Douglas and Rachford (1956), was used.

Some questions have been raised concerning the validity of the assumption that packed fruit and vegetables posses homogeneous permeability. For produce such as oranges, apples and Brussels sprouts, which are close to spherical, resistance to air flow through them may well be considered isotropic, but other produce, such as beans, cucumber, carrots or celery may better be described as having air flow resistance tensors that are transversely orthotropic. Also, the assumption that agricultural produce respires at a constant rate is not accurate. For example, Hardenburg et al (1986) pointed out that respiration rates are highly variable between species, and they are very responsive to the conditions under which produce is stored.

1.3 Objectives

In this study we wish to examine the theory, analysis and practical application of transient, multi-dimensional natural convection in a porous medium, having isotropic or orthotropic

permeability, to heating or cooling of stored agricultural produce packed in closed containers of different size; with different temperature dependent respiration functions.

The key to improving the non-uniform temperature distribution and controlling loss of moisture in packed produce lies in developing an effective method of predicting the velocity and temperature fields for given boundary conditions. To date it appears that few such studies have been attempted and a successful outcome will have considerable direct application to a host of storage problems.

The specific aims of the research program are:

- 1. To formulate the equations governing natural convection in packed agricultural produce, including the mathematical treatment of respiratory heating sources and boundary conditions.
- 2. To apply a numerical analysis process appropriate to solve the form of the governing equations and to evaluate the accuracy and efficiency of the methods used.
- 3. To present numerical results for the heating or cooling of selected packed produce stored in differently sized closed containers under varying boundary and permeability conditions.

CHAPTER 2

RESPIRATION OF AGRICULTURAL PRODUCE AND ITS MATHEMATICAL MODELLING

Fruits and vegetables are living structures even after they are harvested from the field or removed from their stems. They keep respiring and transpiring. These metabolic activities are dependent entirely on food reserves and moisture content.

The main metabolic process taking place in harvested produce is respiration. Respiration can be described as the oxidation breakdown of the more complex materials normally present in cells such as starch, sugars and organic acids, to simpler molecules such as CO₂ and H₂O, with the concurrent production of energy, and other molecules. In most cases respiration involves taking up Oxygen (O₂) and giving off carbon dioxide (CO₂) and heat. Respiration heat directly affects the temperature of the fruits and vegetables. Respiration in fruits and vegetables is mostly under enzymic control. Usually enzymes lose their activity at temperatures above 30 °C but the temperature at which specific enzymes become inactive varies. Many are still active at 35 °C but most are inactive at 40 °C (Wills, 1977).

When fruits and vegetables are held above the temperature at which respiration ceases or becomes abnormal, the structure of the produce may be damaged. The low temperature limit for normal metabolic activity is near the freezing point of the tissue and is usually between 0 °C and -2 °C.

The rate of respiration is principally governed by temperature. The higher the temperature, the faster is the metabolic reaction rate in living produce and the greater the heat generated. Typically, for each 10 °C rise in temperature, the rate of respiration is roughly doubled or tripled. The effect of temperature on agricultural produce is usually expressed in terms of the temperature quotient, Q_{10} , which is defined as follows

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\frac{10}{(t_2 - t_1)}} = constant$$
 (2.1)

where t_1 and t_2 are respiration temperatures (°C) and R_1 and R_2 are the corresponding respiration rates (mg Co₂/kg h). According to Ryall (1979), Q_{10} is not actually a constant and may take any value between 1 and 5. Values of Q_{10} are highest between 0 °C and 10 °C, commonly ranging between 2 and 3. In the temperature range 10 - 32 °C values of Q_{10} tend toward 1.

Table 2.1, from Ryall (1979), contains temperature quotient information derived from the respiration rates of various vegetables. Generally the rate of respiration increases as the temperature of the produce rises from just above its freezing point. At a certain temperature the respiration rate reaches a maximum value; beyond this temperature the respiration rate decreases sharply with temperature, until finally respiration ceases at the thermal death point - see Ryall (1979).

Table 2.1 Temperature quotients (Q_{10}) for rates of respiration of various vegetables (Ryall, 1979)

| Temperature Range (°C) | | | | | | | | |
|------------------------|-----|------|-------|-------|-------|-------|--|--|
| Vegetable | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | | |
| Asparagus | 3.3 | 4.2 | 1.2 | 2.3 | 1.5 | 2.0 | | |
| Beans, snap | | 2.7 | 2.6 | 1.9 | 2.2 | | | |
| Broccoli | 5.2 | 4.6 | 3.9 | 2.7 | | | | |
| Brussels sprouts | 4.9 | 2.7 | 1.5 | | | | | |
| Cabbage | 2.5 | 1.5 | 3.2 | 1.6 | | | | |
| Carrot, roots | 2.0 | 2.3 | 1.5 | 2.8 | | | | |
| Celery | 3.5 | 4.0 | 1.7 | | | | | |
| Potatoes | 2.2 | 3.4 | 2.5 | 2.1 | | | | |
| Tomatoes | | | | 2.6 | 1.5 | 1.2 | | |

Respiration rates of various fruits and vegetables, from Hardenburg (1986), are shown in Table 2.2. The respiration rates have been expressed as rates of carbon dioxide production (mg CO₂/kg·h) at different temperatures. Data from Tables 2.1 and 2.2 were used in equation (2.1) to calculate respiration rates for asparagus and for Brussels sprouts. The results are presented in Table 2.3 and have been compared with the measured values given in Table 2.2.

Although use of the temperature quotient allows moderately good prediction of respiration

rates, it was considered that better results could be obtained by using the method of least squares to obtain a relationship between the measured respiration rates and temperatures. Thus the locally distributed heat source within the packed bed could be readily calculated from the local temperature distribution when used in the numerical model. In developing the least squares model for respiration, it was assumed that at temperatures above 35°C and below freezing point, the heat generation rates were zero. Using the respiration heat generation rates, $Q_i(T_i)$ and corresponding temperatures, T_i known from measurement, a function $Q(i) = \sum_{i=0}^{n} a_i T^i$ can be found by determining the parameters a_i . The subroutine QSOURCE in Appendix D was used in the modelling program. A schematic diagram of a typical respiration rate versus temperature function is shown in Figure 2.1, Ryall and Lipton (1979).

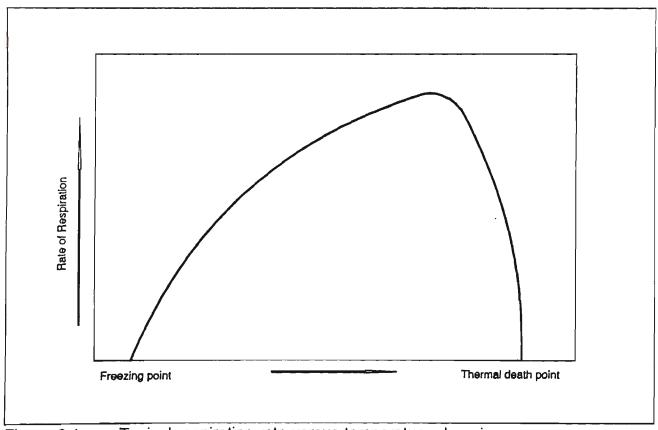


Figure 2.1 Typical respiration rate versus temperature changing.

Table 2.2 Respiration rates of fruits and vegetables, expressed as rates of carbon dioxide production (mg Co₂/kg·h), at various temperatures, from Hardenburg (1986)

| Temperature | | | | | | | |
|------------------------|-------|--------|--------|---------|---------|---------|--|
| Commodity | 0°C | 4-5°C | 10°C | 15-16°C | 20-21°C | 25-27°C | |
| Apples, summer | 3-6 | 5-11 | 14-20 | 18-31 | 20-41 | - | |
| Apples, fall | 2-4 | 5-7 | 7-10 | 9-20 | 15-25 | - | |
| Apricots | 5-6 | 6-9 | 11-19 | 21-34 | 29-52 | - | |
| Asparagus | 27-80 | 55-136 | 90-304 | 160-327 | 275-500 | 500-600 | |
| Beans, snap | 20 | 35 | 58 | 93 | 130 | 193 | |
| Broccoli | 19-21 | 32-37 | 75-87 | 161-186 | 278-320 | - | |
| Brussels sprouts | 10-30 | 22-48 | 63-84 | 64-136 | 86-190 | - | |
| Carrots, topped | 10-20 | 13-26 | 20-42 | 26-54 | 46-95 | - | |
| Carrots, bunched | 18-35 | 25-51 | 32-62 | 55-106 | 87-121 | - | |
| Cauliflower | 16-19 | 19-22 | 32-36 | 43-49 | 75-86 | 84-140 | |
| Celery | 5-7 | 9-11 | 24 | 30-37 | 64 | - | |
| Kiwifruit | 3 | 6 | 12 | - | 16-22 | - | |
| Pears, Bartlett | 3-7 | 5-10 | 8-21 | 15-60 | 30-70 | - | |
| Pears, Kieffer | 2 | - | - | 11-24 | 15-28 | 20-29 | |
| Potatoes, immature | - | 12 | 14-21 | 14-31 | 18-45 | - | |
| Potatoes, mature | - | 3-9 | 7-10 | 6-12 | 8-16 | - | |
| Tomatoes, mature-green | - | 5-8 | 12-18 | 16-28 | 28-41 | 35-51 | |
| Tomatoes, ripening | - | - | 13-16 | 24-29 | 24-44 | 30-52 | |

Table 2.3 Average respiration rate(mg $\text{Co}_2/\text{kg}\cdot\text{h}$): by measured, calculation of Q_{10} and least squares modelling

| | Temperature | 0°C | 5°C | 10°C | 15°C |
|------------------|------------------------|------|------|-------|-------|
| Asparagus | Measurement | 53.5 | 95.5 | 197.0 | 243.5 |
| | Q ₁₀ method | 53.5 | 97.2 | 199.2 | 218.2 |
| | Least squares method | 53.5 | 95.5 | 196.9 | 243.5 |
| Brussels sprouts | Measurement | 20.0 | 35.0 | 73.5 | 100 |
| | Q ₁₀ method | 20.0 | 44.3 | 72.8 | 89.2 |
| | Least squares method | 20.0 | 35.0 | 73.5 | 100 |

CHAPTER 3

THEORY OF NATURAL CONVECTION IN BULK PACKED AGRICULTURAL PRODUCE

3.1 Physical Model and Some Concepts of Porous Medium

Most of the containers for fruits and vegetables storage are rectangular boxes. In this study we consider a physical system with the following characteristics: A rectangular cartesian reference system is used to define a container filled with fruits or vegetables, which are considered as the solid matrix of a porous medium saturated with air, such as shown in Figure 3.1. The respiration heats of fruit and vegetables are treated as internal heat sources which are functions of temperature. The coordinate system is also shown in Figure 3.1; the x axis is along one edge of the rectangular enclosure and \vec{G} is the gravity force.

In order to describe natural convection in bulk-packed fruit or vegetables, the theories on natural convection in porous medium are introduced. The produce inside the container are considered as a porous medium. Beukema(1980,1983) showed that these theories may be applied to quantify the natural convection phenomena that occur in packed beds of agricultural produce. A porous medium is a material consisting of a solid matrix with interconnecting voids. As Dullien (1979) pointed out, a material or a structure must pass at lease one of the following two tests in order to qualify as a porous medium:

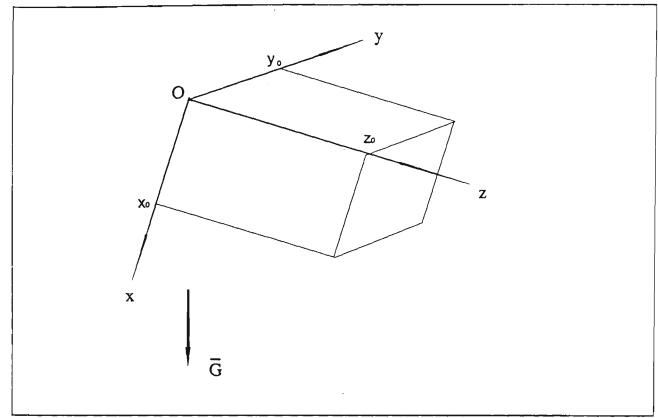


Figure 3.1 Coordinate system used in this study

- (1) It must contain spaces, so-called pores or voids, free of solids, imbedded in the solid or semisolid matrix. The pores usually contain some fluid, such as air, or a mixture of different fluids.
- (2) It must be permeable to a variety of fluids, ie, fluids should be able to penetrate through one face of a spectrum made of the material and emerge on the other side.

 From these points of view, packed fruits and vegetables can be classed as porous medium.

Porosity ε plays an important role in a porous medium and is defined as the fraction of the total volume of the medium that is occupied by void space. Then 1- ε is the fraction that is occupied by solid, Nield and Bejan (1992). In order to carefully analyze systems in which natural convection is taking place, we must construct a continuum model for the porous medium based on the representative elementary volume (r.e.v.) concept. We introduce a cartesian reference system, as shown in Figure 3.2, the r.e.v. is such a control

volume which is very large compared with the pore volumes but very small compared with the macroscopic (whole) flow domain.

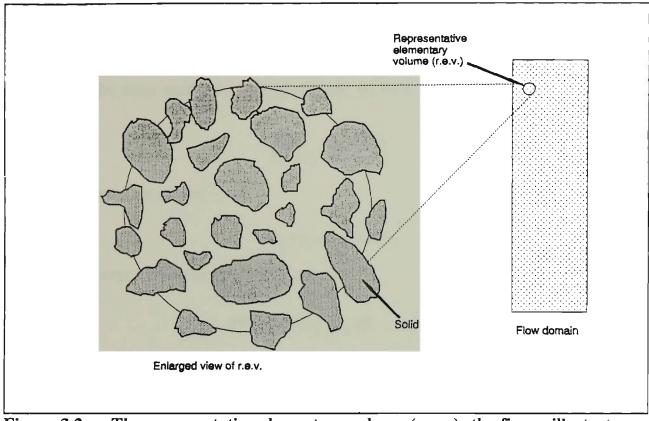


Figure 3.2 The representative elementary volume (r.e.v.): the figure illustrates.

A distinction is made between an average taken with respect to the volume \hat{V}_p of r.e.v. (incorporating both solid and air) and one taken with respect to a volume element \hat{V}_f consisting of fluid only. So we have two velocities according to these two different averages. One is the seepage velocity \vec{V}_p and another is the intrinsic velocity \vec{V}_f . The Dupuit-Forchheimer relationship is

$$\vec{V}_p = \epsilon \vec{V}_f \tag{3.1}$$

In this thesis, unless specifically indicated, the velocity refers to seepage velocity, which is the average of fluid velocity over the porous medium control volume \hat{V}_{p} .

3.2 Continuity Equation

The principle of conservation of mass can be stated as:

(Time rate of change of the mass of the r.e.v.)=0
$$(3.2)$$

considering the mass inside the control volume, we have

$$\frac{d}{dt} \left(\int_{\hat{V}_p} \rho_p \, d\hat{V} \right) = 0 \tag{3.3}$$

 ρ_p is a function of x,y,z and t, viz

$$\rho_p = \rho_p(x, y, z, t) \tag{3.4}$$

From the concept of porous medium, we have

$$\int_{\hat{V}_{p}} \rho_{p} d\hat{V} = (1 - \epsilon) \int_{\hat{V}_{s}} \rho_{s} d\hat{V} + \epsilon \int_{\hat{V}_{f}} \rho_{f} d\hat{V}$$
(3.5)

where ρ_s is the density of solid matrix, ρ_f is the density of fluid.

Because ε and ρ_s are independent of time,

$$\frac{d}{dt}(\int_{\hat{V}_p} \rho_p d\hat{V} = \epsilon \frac{d}{dt} \int_{\hat{V}_f} \rho_f d\hat{V} = 0$$
 (3.6)

Application of the Reynolds transport theorem equation 3.6 leads to

$$\epsilon \frac{d}{dt} \int_{\hat{V}_p} \rho_p d\hat{V} = \epsilon \int_{\hat{V}_f} \frac{\partial \rho_f}{\partial t} d\hat{V} + \epsilon \int_{A_f} \rho_f \vec{V}_f \cdot \vec{n} \, dA = 0$$
 (3.7)

Using the divergence theorem, equation 3.7 changes to

$$\int_{\hat{V}_{f}} \left[\epsilon \frac{\partial \rho_{f}}{\partial t} + \epsilon \nabla \cdot (\rho_{f} \vec{V}_{f}) \right] d\hat{V} = 0$$
(3.8)

Since the control volume is arbitrary and ρ , V are assumed to be continuous functions with continuous derivatives, the integrand in the integral must be zero and we obtain the

continuity equation:

$$\epsilon \frac{\partial \rho_f}{\partial t} + \nabla \cdot (\rho_f \vec{V}_p) = 0$$
 (3.9)

where $\epsilon \frac{\partial \rho_f}{\partial t}$ indicates the rate of mass increase within the control volume, and $-\nabla \cdot (\rho_f \vec{V}_p)$ denotes the net mass flux into the volume. Since mass cannot be generated or destroyed, these two terms must be equal.

To simplify this equation, it is assumed that the environment pressure, ie, atmospheric pressure remains constant and the fluid, air, is incompressible, ie, its properties remain constant except for the density variation in producing the buoyancy force. Finally equation 3.9 becomes

$$\nabla \cdot \vec{V}_p = 0 \tag{3.10}$$

3.3 Momentum Equation: Darcy's Law

The principle of momentum conservation may be stated as

(the time rate of changing of linear momentum of the r.e.v.)
$$= (the force acting on the r.e.v.)$$
(3.11)

Before we discuss the momentum equation, some assumptions are introduced. The properties of the fluid are isotropic except the density which will satisfy the Boussiniq approximation.

In 1856, from his experiments on the flow through horizontally stratified beds of sand, Henri Darcy concluded the relationship between flow rate and the pressure drop. Now termed Darcy's law, it has the form in modern notation:

$$V_p = -\frac{\kappa}{\mu} \nabla p \tag{3.12}$$

where the ∇P is the pressure gradient. μ is the dynamic viscosity of the fluid. κ is the permeability. It depends on the geometry of the porous medium and in here it represents isotropic permeability.

An alternative to Darcy's law is Brinkman's equation with the Boussinesq approximation, ie, the buoyancy force is due to the density variation and the gravity acceleration, and the buoyancy force is the main factor in producing natural convection. So we have

$$\rho_{f}\left[\frac{\partial \vec{V}_{f}}{\partial t} + (\vec{V}_{f} \cdot \nabla) \vec{V}_{f}\right] = -\nabla P - \frac{\mu}{\kappa} \vec{V}_{p} + \tilde{\mu} \nabla^{2} \vec{V}_{p} + \vec{G}$$
(3.13)

where $\tilde{\mu}$ is a effective viscosity and may have a different value than the viscosity of the fluid. Neale and Nader (1974) pointed out that they can take the same value. \vec{G} is the body force.

Many authors (e.g. Rudraiah and Prabhamani, 1974; Neale and Nader 1974; Gasser and Kazimi, 1976; Walker and Homsy, 1977; Tong and Subramanian, 1985; Beckermann, et al 1987; Singh, et al 1993) used Brinkman's equation to describe natural convection in porous medium. However, Chan, Ivey and Barry (1970), found that the contribution of the viscous term $\mu \nabla^2 \vec{V}_p$ is very small even in low Rayleigh number. Furthermore Whitaker (1966,1969) has shown that the Darcy term $\frac{\mu}{\kappa} \vec{V}_p$ replaces the viscous force and therefore

it is incorrect to use both terms in the momentum equation. In this study we also neglected these terms based on the following analysis:

$$\mu = \tilde{O}(2 \times 10^{-5}) \tag{3.14}$$

$$K = \tilde{O}(2 \times 10^{-6}) \tag{3.15}$$

$$\tilde{\mu} = \tilde{O}(2 \times 10^{-5}) \tag{3.16}$$

$$\frac{\mu}{K}\vec{V}_{p} = \tilde{O}(10)\vec{V}_{p} \tag{3.17}$$

$$\mu \nabla^2 \vec{V}_p = \tilde{O}(2 \times 10^{-6}) \vec{V}_p \tag{3.18}$$

Thus we have:

$$\frac{\mu}{K}\vec{V}_{p} > \mu \nabla^{2}\vec{V}_{p} \tag{3.19}$$

Compared to the resistance of solid matrix, the viscous resistance term is much smaller.

Beck(1972) pointed out that inclusion of the $(\vec{V}_p \cdot \nabla)\vec{V}_p$ term was inappropriate and furthermore Nield(1992) suggested to drop this term in the equation. He showed that in the case of a viscous fluid a material particle retains its momentum in the absence of applied forces when it is displaced from a point A to a neighbouring arbitrary point B. But in a porous medium with a fixed solid matrix this is not so, in general, because some solid material impedes the motion and causes a change in momentum. Thus it is not rational to include the convective term $(\vec{V} \cdot \nabla)\vec{V}$ in the momentum equation unless the porosity is very large, and in that case it can be queried whether one really has a porous medium, in the usual sense of that term, as distinct from a fluid in which there are some solid obstructions. For the same reason it does not make sense to talk about turbulence on a macroscopic scale in a natural porous medium because one can not have unimpeded eddies of arbitrary size.

We can also drop the time derivative term $\rho_f \frac{\partial \vec{V}_f}{\partial t}$ because in general the transients decay rapidly. With these terms dropped we finally have the momentum equation in isotropic permeability porous medium.

$$-\nabla P - \frac{\mu}{\kappa} \vec{V}_p + \vec{G} = 0 \tag{3.20}$$

This is actually Darcy's law.

Many of the fruits and vegetable have spherical shapes and can be treated as isotropic porous medium. But many others have cylindrical shapes and can be considered as an orthotropic permeability porous medium. As shown in Figure 3.3, orthotropic permeability is a second order symmetric diagonal tensor having different permeability in component x, y, z directions.

$$\mathbf{K} = \begin{vmatrix} \kappa_x & 0 & 0 \\ 0 & \kappa_y & 0 \\ 0 & 0 & \kappa_z \end{vmatrix}$$
 (3.21)

Permeability is related to the pore size distribution, since the distribution of the pore sizes and directions entrances and exits, and lengths of the pore walls constitutes the primary resistance.

Permeability is a function of porosity, tortuosity and connectivity. Tortuosity is defined as the relative average length of a flow path, ie, the avenge length of the flow paths to the length of the medium. Connectivity defines the arrangement and number of pore connections. Although permeability is related to these parameters, none of them can be used alone to predict the permeability. Normally the structure of a real porous medium is

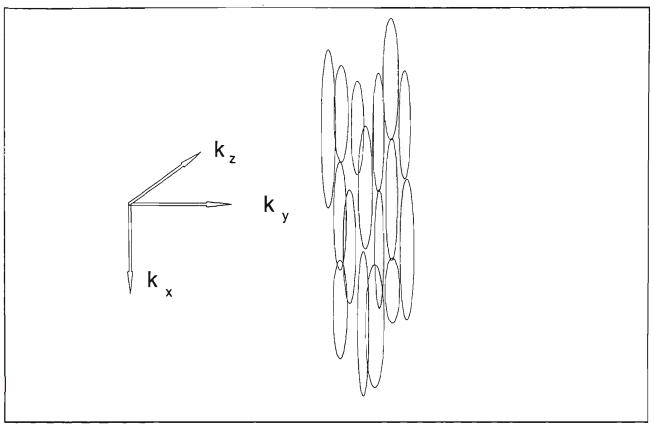


Figure 3.3 Orthotropic permeability arising as a result of alignment of the commodities in the gravitational field

complicated and it is rarely possible to predict the permeability theoretically. Experimental data are the main source of quantifying permeability.

A well-known expression of permeability for packed spherical particles is the Carman-Kozeny formula:

$$\kappa = \frac{D_{eff}^2 \epsilon^3}{180 (1 - \epsilon)^2}$$
 (3.22)

where $D_{\it eff}$ is the effective diameter of the particles or is called volume-surface mean diameter

$$D_{eff} = \frac{6}{S_{v}} \tag{3.23}$$

Here S_{ν} is the specific surface, ie, surface of solids per unit volume of solids.

Many authors have used the Carman-Kozeny formula to determine the permeability, for example, Nield (1991). However, Ergun (1952) pointed out that the permeability should have the form

$$\kappa = \frac{D_{\text{eff}}^2 \epsilon^3}{150(1-\epsilon)^2} \tag{3.24}$$

Plumb and Huenefeld (1981) and Beckermann al et (1987) quoted Ergun's finding but actually Beckermann al et (1987) modified the constant from 150 to 175 and used

$$\kappa = \frac{D_{\text{eff}}^2 \epsilon^3}{175 (1 - \epsilon)^2} \tag{3.25}$$

in their work.

In order to predict the permeability of packed apples, oranges etc. having spherical shapes the Carman-Kozeny formula was employed in this study. Because of their non-spherical shape, packaged beans, carrots, celery etc, possess permeabilities which vary in different directions. No study related to predicting orthotropic permeability was found in the literature. Nevertheless, one common pattern is discussed below.

As shown in Figure 3.3, if the commodities are placed parallel to each other and the x axis is along their axis line, we may assume that

$$\mathbf{K}_{z} = \mathbf{K}_{y} = \mathbf{a} \mathbf{K}_{z} \tag{3.26}$$

Where a is a proportional constant.

For simplicity, assume that the spaces between commodities are channels and the channels are connected from head to head and can be thought of as a pipe having an effective radius

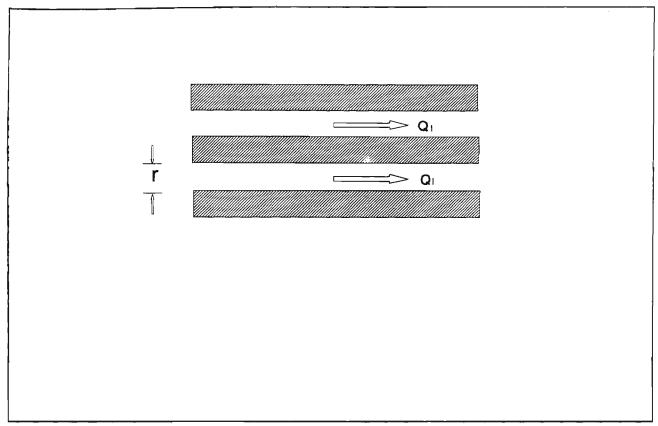


Figure 3.4 Flow model based on parallel, uniform channels

r, as shown in Figure 3.4, Applying theory of fluid flow in pipes, we have the equation for laminar flow rate in a single pipe,

$$Q_i = \frac{\pi r^4}{8\mu} \frac{\Delta P}{L} \tag{3.27}$$

where ΔP is the pressure drop.

For N pipes the total flow rate is given by

$$Q = NQ_i = \frac{N\pi r^4}{8\mu} \cdot \frac{\Delta P}{L} \tag{3.28}$$

applying Darcy's law in the x direction, we obtain

$$Q = SV_p = S \cdot \frac{\kappa_x}{\mu} \cdot \frac{\Delta P}{L}$$
 (3.29)

where S is the cross-sectional area.

Combining the above equations and eliminating Q. We have

$$\kappa_{x} = \frac{N\pi r^4}{8S} \tag{3.30}$$

Thus

$$\kappa_{x} = \frac{N\pi r^{4}}{8S} = \frac{n\pi r^{4}}{8} \tag{3.31}$$

where, n = number of channels per unit cross-sectional area.

The lack of a rigorously valid method for determining the radius and the number of channels in a randomly packed porous medium is a difficulty that has often been raised. In practice however, a number of well-grounded approximations have been developed and may be used in the Darcy equation.

For orthotropic permeability porous media, the momentum equation reduces to

$$-\nabla P - \frac{\mu}{\mathbf{K}} \vec{V}_p + \vec{G} = 0 \tag{3.32}$$

3.4 Energy Equation

In order to derive the thermal energy transport equation that governs heat transfer in packed beds certain assumptions must be made. Suppose the viscous dissipation were neglected. The atmospheric pressure is constant and the work done by pressure change is also negligible. The radiative heat transfer may be ignored due to the temperature difference being small. The properties of fluid and solid are constant and isotropically homogenous.

The conservation of energy can be stated as

(the amount of heat for temperature change incontrol volume)
=(the amount of heat transfer due toconvection)
+(the amount of heat due to conduction)
+(the amount of heat due to internal heat generation)

(3.33)

Expressed mathematically, we have

$$(\rho C)_{p} \frac{\partial T}{\partial t} = -(\rho C_{p})_{f} \vec{V}_{p} \cdot \nabla T + k_{eff} \nabla^{2} T + Q_{heat}$$
(3.34)

where

$$(\rho C)_p = (1 - \varphi)(\rho C)_s + \varphi(\rho C_p)_f \tag{3.35}$$

C is specific heat of the solid,

 C_p is specific heat of the fluid at constant pressure,

 $Q_{\textit{heat}}$ is the heat production, W/m^3

 k_{eff} is the effective thermal conductivity of porous medium.

The basic conservation equations of mass, momentum, and energy are

$$\nabla \cdot \vec{V}_{p} = 0 \tag{3.10}$$

$$-\nabla P - \frac{\mu}{\mathbf{K}} \vec{V}_p + \vec{G} = 0 \tag{3.32}$$

$$(\rho C)_{p} \frac{\partial T}{\partial t} = -(\rho C_{p})_{f} \vec{V}_{p} \cdot \nabla T + k_{eff} \nabla^{2} T + Q_{heat}$$
(3.34)

3.5 General Boundary Conditions

We consider that the walls of the enclosure are not permeable, ie, $V_n=0$, where the subscript n indicate a normal component to the walls.

The boundary conditions of momentum equation in detail are as shown below:

$$x=0: V_{x}=0$$
 (3.36)

$$x = X_0$$
 $V_x = 0$ (3.37)

$$y=0: V_{y}=0$$
 (3.38)

$$y = Y_0$$
 $V_y = 0$ (3.39)

$$z=0: V_{z}=0$$
 (3.40)

$$z = Z_0 V_z = 0 (3.41)$$

The boundary conditions for the energy equation (3.34) can reflect any of the heat transfer mechanisms listed below:

Heatflux
$$\frac{\partial T}{\partial n} = Constant \neq 0$$
 (3.42)

Adiabatic
$$\frac{\partial T}{\partial n} = 0 \tag{3.43}$$

Isothermal
$$T=Constant$$
 (3.44)

Convective
$$-k_{eff} \frac{\partial T}{\partial n} = \alpha_n (T - T_c)$$
 (3.45)

Here n represents the x or y or z axis.

3.6 Vector-Potential Formulation: A Transform of Momentum Equation

The momentum equation (3.32) is written in the terms of the primitive variables, pressure and velocity. We may solve the set of equations in this form, as for example has Williams (1969) and Chorin(1968). Alternatively, we may solve them in terms of the vector potential, as has Mallinson(1973). Some benefits are obtained by using this approach. It reduces the number of equations to be solved by one and it ensures the continuity equation is automatically satisfied. The pressure term is eliminated and thus the difficulties associated with pressure boundary conditions are avoided. Aziz and Hellums(1967) found

that the iterative procedure based on the primitive variable equations was less satisfactory in its convergence behaviour.

According to the continuity equation, $\nabla \cdot \vec{V}_p = 0$, thus, V_p is a solenoidal; it can be shown, Hirasaki and Hellums (1970), that it is always possible to define a vector potential ψ and a scalar potential ϕ as

$$\vec{V}_{p} = \nabla \times \vec{\Psi} - \nabla \Phi \tag{3.46}$$

$$\nabla \cdot \psi = 0 \tag{3.47}$$

$$\nabla^2 \mathbf{\Phi} = \mathbf{0} \tag{3.48}$$

hence ψ is also solenoidal and ϕ satisfies the Laplace equation.

So we have the following relation

$$\nabla \times \vec{V}_{p} = \nabla \times (\nabla \times \vec{\psi} - \nabla \phi)$$

$$= \nabla \times \nabla \times \vec{\psi} - \nabla \times \nabla \phi$$

$$= \nabla \times \nabla \times \vec{\psi}$$

$$= \nabla (\nabla \cdot \vec{\psi}) - \nabla^{2} \vec{\psi}$$

$$= -\nabla^{2} \vec{\psi}$$

$$= -\nabla^{2} \vec{\psi}$$
(3.49)

By taking the curl of equation (3.32), we have

$$-\nabla \times \nabla P - \nabla \times (\frac{\mu}{\mathbf{K}} \vec{V}_p) + \nabla \times \vec{G} = 0$$
 (3.50)

Using (3.46) and treating μ as constant, we have

$$\nabla \times (\frac{1}{\overline{\mathbf{K}}} \nabla \times \mathbf{\psi}) - \nabla \times (\frac{1}{\overline{\mathbf{K}}} \nabla \mathbf{\phi}) = \frac{1}{\mu} \nabla \times \vec{G}$$
 (3.51)

To obtain the component equations of 3.51, firstly we expand each term. So we find:

$$\frac{1}{\overline{\mathbf{K}}} = \overline{\mathbf{K}}^{-1} = \begin{vmatrix} \frac{1}{\kappa_x} & 0 & 0 \\ 0 & \frac{1}{\kappa_y} & 0 \\ 0 & 0 & \frac{1}{\kappa_z} \end{vmatrix}$$
(3.52)

$$\nabla \times (\mathbf{K}^{-1} \nabla \Phi) = \nabla \times \begin{bmatrix} \left| \frac{1}{\kappa_{x}} & 0 & 0 \right| \left(\frac{\partial \Phi}{\partial y} \right) \\ 0 & \frac{1}{\kappa_{y}} & 0 \\ 0 & 0 & \frac{1}{\kappa_{z}} \right| \left(\frac{\partial \Phi}{\partial y} \right) \\ \frac{\partial \Phi}{\partial y} & \frac{\partial \Phi}{\partial z} \end{bmatrix} (\vec{i} + \vec{j} + \vec{k}) \end{bmatrix}$$

$$= \nabla \times \left(\frac{1}{\kappa_{x}} \frac{\partial \Phi}{\partial x} \vec{i} + \frac{1}{\kappa_{y}} \frac{\partial \Phi}{\partial y} \vec{j} + \frac{1}{\kappa_{z}} \frac{\partial \Phi}{\partial z} \vec{k} \right)$$

$$= \frac{\partial^{2} \Phi}{\partial y \partial z} \left(\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{y}} \right) \vec{i} + \frac{\partial^{2} \Phi}{\partial x \partial z} \left(\frac{1}{\kappa_{x}} - \frac{1}{\kappa_{z}} \right) \vec{j} + \frac{\partial^{2} \Phi}{\partial x \partial y} \left(\frac{1}{\kappa_{y}} - \frac{1}{\kappa_{x}} \right) \vec{k}$$

$$\nabla \times (\mathbf{K}^{-1} \nabla \times \vec{\Psi}) = \left[\frac{1}{\kappa_{z}} \left(\frac{\partial^{2} \Psi_{y}}{\partial x \partial y} - \frac{\partial^{2} \Psi_{x}}{\partial y^{2}} \right) + \frac{1}{\kappa_{y}} \left(\frac{\partial^{2} \Psi_{z}}{\partial x \partial z} - \frac{\partial^{2} \Psi_{x}}{\partial z^{2}} \right) \right] \vec{i}$$
(3.53)

$$\nabla \times (\mathbf{K}^{-1} \nabla \times \vec{\Psi}) = \left[\frac{1}{\kappa_{z}} \left(\frac{\partial^{2} \Psi_{y}}{\partial x \partial y} - \frac{\partial^{2} \Psi_{x}}{\partial y^{2}} \right) + \frac{1}{\kappa_{y}} \left(\frac{\partial^{2} \Psi_{z}}{\partial x \partial z} - \frac{\partial^{2} \Psi_{x}}{\partial z^{2}} \right) \right] \vec{i}$$

$$+ \left[\frac{1}{\kappa_{x}} \left(\frac{\partial^{2} \Psi_{z}}{\partial y \partial z} - \frac{\partial^{2} \Psi_{y}}{\partial z^{2}} \right) + \frac{1}{\kappa_{z}} \left(\frac{\partial^{2} \Psi_{x}}{\partial x \partial y} - \frac{\partial^{2} \Psi_{y}}{\partial x^{2}} \right) \right] \vec{j}$$

$$+ \left[\frac{1}{\kappa_{y}} \left(\frac{\partial^{2} \Psi_{x}}{\partial x \partial z} - \frac{\partial^{2} \Psi_{z}}{\partial x^{2}} \right) + \frac{1}{\kappa_{x}} \left(\frac{\partial^{2} \Psi_{y}}{\partial y \partial z} - \frac{\partial^{2} \Psi_{z}}{\partial y^{2}} \right) \right] \vec{k}$$

$$(3.54)$$

Because ψ is solenoidal, we may write

$$\nabla(\nabla \cdot \vec{\Psi}) = \left(\frac{\partial^2 \Psi_x}{\partial x^2} + \frac{\partial^2 \Psi_y}{\partial x \partial y} + \frac{\partial^2 \Psi_z}{\partial x \partial z}\right) \vec{i}$$

$$+ \left(\frac{\partial^2 \Psi_x}{\partial x \partial y} + \frac{\partial^2 \Psi_y}{\partial y^2} + \frac{\partial^2 \Psi_z}{\partial y \partial z}\right) \vec{j}$$

$$+ \left(\frac{\partial^2 \Psi_x}{\partial x \partial z} + \frac{\partial^2 \Psi_y}{\partial y \partial z} + \frac{\partial^2 \Psi_z}{\partial z^2}\right) \vec{k}$$

$$= \mathbf{0}$$
(3.55)

thus it follows that

$$\frac{\partial^2 \psi_y}{\partial x \partial y} = -\frac{\partial^2 \psi_x}{\partial x^2} - \frac{\partial^2 \psi_z}{\partial x \partial z}$$
 (3.56)

$$\frac{\partial^2 \psi_x}{\partial x \partial y} = -\frac{\partial^2 \psi_y}{\partial y^2} - \frac{\partial^2 \psi_z}{\partial y \partial z}$$
 (3.57)

$$\frac{\partial^2 \psi_x}{\partial x \partial z} = -\frac{\partial^2 \psi_z}{\partial z^2} - \frac{\partial^2 \psi_y}{\partial y \partial z}$$
 (3.58)

Using the relationships of (3.56) to (3.58), equation (3.54) may deform to

$$\nabla \times (\mathbf{K}^{-1} \nabla \times \vec{\psi}) = -\left[\frac{1}{\kappa_{z}} \frac{\partial^{2} \psi_{x}}{\partial x^{2}} + \frac{1}{\kappa_{z}} \frac{\partial^{2} \psi_{x}}{\partial y^{2}} + \frac{1}{\kappa_{y}} \frac{\partial^{2} \psi_{x}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{y}}) \frac{\partial^{2} \psi_{z}}{\partial x \partial z} \right] \vec{i}$$

$$-\left[\frac{1}{\kappa_{z}} \frac{\partial^{2} \psi_{y}}{\partial x^{2}} + \frac{1}{\kappa_{z}} \frac{\partial^{2} \psi_{y}}{\partial y^{2}} + \frac{1}{\kappa_{x}} \frac{\partial^{2} \psi_{y}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{x}}) \frac{\partial^{2} \psi_{z}}{\partial y \partial z} \right] \vec{j}$$

$$-\left[\frac{1}{\kappa_{y}} \frac{\partial^{2} \psi_{z}}{\partial x^{2}} + \frac{1}{\kappa_{x}} \frac{\partial^{2} \psi_{z}}{\partial y^{2}} + \frac{1}{\kappa_{y}} \frac{\partial^{2} \psi_{z}}{\partial z^{2}} + (\frac{1}{\kappa_{x}} - \frac{1}{\kappa_{y}}) \frac{\partial^{2} \psi_{y}}{\partial y \partial z} \right] \vec{k}$$

$$(3.59)$$

Using equation (3.53) and (3.59) in equation (3.51), we find the x, y, z component equations:

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{x}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{y}})(\frac{\partial^{2}\psi_{z}}{\partial x\partial z} + \frac{\partial^{2}\phi}{\partial y\partial z})\right] = \frac{1}{\mu}(\frac{\partial G_{z}}{\partial y} - \frac{\partial G_{y}}{\partial z}) (3.60)$$

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{y}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{y}}{\partial y^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{y}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{x}})(\frac{\partial^{2}\psi_{z}}{\partial y\partial z} - \frac{\partial^{2}\phi}{\partial x\partial z})\right] = \frac{1}{\mu}(\frac{\partial G_{x}}{\partial z} - \frac{\partial G_{z}}{\partial x}) (3.61)$$

$$-\left[\frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial x^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{z}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial z^{2}} + (\frac{1}{\kappa_{x}} - \frac{1}{\kappa_{y}})(\frac{\partial^{2}\psi_{y}}{\partial y\partial z} - \frac{\partial^{2}\phi}{\partial x\partial z})\right] = \frac{1}{\mu}(\frac{\partial G_{y}}{\partial z} - \frac{\partial G_{x}}{\partial z}) (3.62)$$

where G_x, G_y, G_z are x, y, z components of the buoyancy force.

The general expression for the body force acting in x,y,z directions is developed when the container in such a position that none of the edges are along the gravity acceleration. Referring to Figure 3.5 we may write

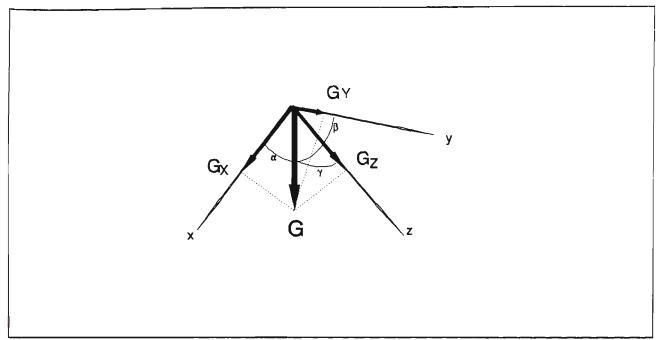


Figure 3.5 x, y, z components of G

$$G_{r} = G\cos\alpha \tag{3.63}$$

$$G_{v} = G \cos \beta \tag{3.64}$$

$$G_{z} = G \cos \gamma \tag{3.65}$$

$$\vec{G}_{x} + \vec{G}_{y} + \vec{G}_{z} = \vec{G} = g \rho_{0} \beta_{0} (T - T_{0}) (\cos \alpha \vec{i} + \cos \beta \vec{j} + \cos \vec{\gamma})$$
 (3.66)

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1 \tag{3.67}$$

Equations (3.60) to (3.67) may be combined to yield the following equations

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{x}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{y}})(\frac{\partial^{2}\psi_{z}}{\partial x \partial z} + \frac{\partial^{2}\phi}{\partial y \partial z})\right] = \frac{g\rho_{0}\beta_{0}}{\mu}(\cos\gamma\frac{\partial T}{\partial y} - \cos\beta\frac{\partial T}{\partial z})$$
(3.68)

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{y}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{y}}{\partial y^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{y}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{x}})(\frac{\partial^{2}\psi_{z}}{\partial y\partial z} - \frac{\partial^{2}\phi}{\partial x\partial z})\right] = \frac{g\rho_{0}\beta}{\mu_{f}}(\cos\alpha\frac{\partial T}{\partial z} - \cos\gamma\frac{\partial T}{\partial z})$$
(3.69)

$$-\left[\frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial x^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{z}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial z^{2}} + (\frac{1}{\kappa_{x}} - \frac{1}{\kappa_{y}})(\frac{\partial^{2}\psi_{y}}{\partial y\partial z} - \frac{\partial^{2}\phi}{\partial x\partial y})\right] = \frac{g\rho_{0}\beta}{\mu_{f}}(\cos\beta\frac{\partial T}{\partial x} - \cos\alpha\frac{\partial T}{\partial y})$$
(3.70)

When one of the container edges is along gravity direction, say, x axis, then α =0 and β = γ =90°. So we have

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{x}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{y}})(\frac{\partial^{2}\psi_{z}}{\partial x \partial z} + \frac{\partial^{2}\phi}{\partial y \partial z})\right] = 0$$
(3.71)

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\Psi_{y}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\Psi_{y}}{\partial y^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\Psi_{y}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{x}})(\frac{\partial^{2}\Psi_{z}}{\partial y\partial z} - \frac{\partial^{2}\Phi}{\partial x\partial z})\right] = \frac{g\rho_{0}\beta}{\mu_{f}}\frac{\partial T}{\partial z}$$
(3.72)

$$-\left[\frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial x^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{z}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial z^{2}} + (\frac{1}{\kappa_{x}} - \frac{1}{\kappa_{y}})(\frac{\partial^{2}\psi_{y}}{\partial y\partial z} - \frac{\partial^{2}\phi}{\partial x\partial y})\right] = -\frac{g\rho_{0}\beta}{\mu_{f}}\frac{\partial T}{\partial y}$$
(3.73)

3.7 Boundary Condition on ψ and ϕ

For incompressible fluid flows bounded by a solid surface, the scalar potential φ is specified to have the boundary condition set out below, Hirasaki and Hellums (1970)

$$\vec{n} \cdot \nabla \phi = \frac{\partial \phi}{\partial n} = -\vec{n} \cdot \vec{V}_p = 0$$
 (3.74)

In more detail,

$$x = 0 \qquad \frac{\partial \Phi}{\partial x} = 0 \tag{3.75}$$

$$x = x_0 \qquad \frac{\partial \Phi}{\partial x} = 0 \tag{3.76}$$

$$y = 0 \qquad \frac{\partial \Phi}{\partial y} = 0 \tag{3.77}$$

$$y = y_0 \qquad \frac{\partial \Phi}{\partial y} = 0 \tag{3.78}$$

$$z = 0 \qquad \frac{\partial \Phi}{\partial z} = 0 \tag{3.79}$$

$$z = z_0 \qquad \frac{\partial \Phi}{\partial z} = 0 \tag{3.80}$$

With equation 3.48 and the above conditions, it can be proved that ϕ is an arbitrary constant (see Appendix A). It means that $\frac{\partial^2 \phi}{\partial y \partial z}$, $\frac{\partial^2 \phi}{\partial x \partial z}$ and $\frac{\partial^2 \phi}{\partial x \partial y}$ equal 0 in

equations (3.71), (3.72) and (3.73). Thus the equations are simplified as follows:

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{x}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{x}}{\partial z^{2}} + \left(\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{y}}\right)\frac{\partial^{2}\psi_{z}}{\partial x \partial z}\right] = \frac{g\rho_{0}\beta}{\mu_{f}}(\cos\gamma\frac{\partial T}{\partial y} - \cos\beta\frac{\partial T}{\partial z})$$
(3.81)

$$-\left[\frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{y}}{\partial x^{2}} + \frac{1}{\kappa_{z}}\frac{\partial^{2}\psi_{y}}{\partial y^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{y}}{\partial z^{2}} + (\frac{1}{\kappa_{z}} - \frac{1}{\kappa_{x}})\frac{\partial^{2}\psi_{z}}{\partial y\partial z}\right] = \frac{g\rho_{0}\beta}{\mu_{f}}(\cos\alpha\frac{\partial T}{\partial z} - \cos\gamma\frac{\partial T}{\partial x})$$
(3.82)

$$-\left[\frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial x^{2}} + \frac{1}{\kappa_{x}}\frac{\partial^{2}\psi_{z}}{\partial y^{2}} + \frac{1}{\kappa_{y}}\frac{\partial^{2}\psi_{z}}{\partial z^{2}} + (\frac{1}{\kappa_{x}} - \frac{1}{\kappa_{y}})\frac{\partial^{2}\psi_{y}}{\partial y\partial z}\right] = \frac{g\rho_{0}\beta}{\mu_{f}}(\cos\beta\frac{\partial T}{\partial x} - \cos\alpha\frac{\partial T}{\partial y})$$
(3.83)

Also the definition of ψ may be simplified from that given in equation (3.46) to:

$$\vec{V}_p = \nabla \times \Psi \tag{3.46a}$$

Hirasaki and Hellums (1968) and Richardson and Cornish(1977) have shown the boundary conditions for ψ should satisfy following conditions:

x=0 and $x=x_0$

$$\frac{\partial \psi_x}{\partial r} = 0 \qquad \psi_y = 0 \qquad \psi_z = 0 \tag{3.84}$$

x=0 and $x=x_0$

$$\frac{\partial \psi_{y}}{\partial y} = 0 \qquad \psi_{x} = 0 \qquad \psi_{z} = 0 \tag{3.85}$$

x=0 and $x=x_0$

$$\frac{\partial \psi_z}{\partial z} = 0 \qquad \psi_x = 0 \qquad \psi_y = 0 \tag{3.86}$$

Considering equation (3.81) and the boundary condition (3.84), in the case of $\kappa_z = \kappa_y$ the

equation changes to

$$\nabla^2 \psi_{\mathbf{r}} = 0 \tag{3.87}$$

and thus ψ_x is zero and the number of equation to be solved has been reduced by one. When $\kappa_x \neq \kappa_y$ or the x axis is not along the gravity direction, ψ_x is not zero and this equation must be solved numerically.

3.8 Non-Dimensional Equations

The solution of equations (3.34), (3.81), (3.82) and (3.83) and their boundary conditions is dependant on the following physical properties of the fluid and the solid matrix of the porous medium - ρ_f , ρ_s , $(C_P)_f$, C_s , k_{eff} , μ , $\overline{\mathbf{K}}$, T_{start} and T_c . Each must be specified before a numerical solution can be obtained and the solution must be repeated entirely if any of them are varied.

The number of parameters can be reduced, and the range of applicability of a solution can be extended if the equations and the boundary conditions are recast in terms of non-dimensional variables and parameters.

Non-dimensionalisation can be performed by using the following non-dimensional variables

$$x' = \frac{x}{x_0} \tag{3.88}$$

$$y' = \frac{y}{x_0} \tag{3.89}$$

$$z' = \frac{z}{x_0} \tag{3.90}$$

$$\nabla' = x_0 \nabla \tag{3.91}$$

$$\nabla^{/2} = x_0^2 \nabla^2 \tag{3.92}$$

$$\theta = \frac{T - T_c}{T_b - T_c} \tag{3.93}$$

$$\psi' = \frac{(\rho C_p)_f}{k_{eff}} \psi \tag{3.94}$$

$$V_{p}' = \frac{(\rho C_{p})_{f} x_{0}}{k_{eff}} V_{p}$$
 (3.95)

$$t' = \frac{k_{eff}}{(\rho C_p)_f x_0^2} t$$
 (3.96)

Re-casting equation (3.34) leads to

$$\frac{\partial \theta}{\partial t'} = -R_c \vec{V'}_p \cdot \nabla' \theta + R_c \nabla'^2 \theta + \frac{R_c Q_{heat} x_0^2}{(T_h - T_c) k_{eff}}$$
(3.97)

where

$$R_c = \frac{(\rho C_p)_f}{(\rho C)_p} \tag{3.97a}$$

equations (3.81), (3.82) and (3.83) change to

$$\frac{\partial^2 \psi'_x}{\partial x^2} + \frac{\partial^2 \psi'_x}{\partial y^2} + \frac{Da_z}{Da_y} \frac{\partial^2 \psi'_x}{\partial z'^2} + (1 - \frac{Da_z}{Da_y}) \frac{\partial^2 \psi'_z}{\partial x' \partial z'} = 0$$
 (3.98)

$$\frac{\partial^2 \psi'_y}{\partial x'^2} + \frac{\partial^2 \psi'_y}{\partial y'^2} + \frac{Da_z}{Da_x} \frac{\partial^2 \psi'_y}{\partial z'^2} + (1 - \frac{Da_z}{Da_x}) \frac{\partial^2 \psi'_z}{\partial y' \partial z'} + Ra Da_z \cos \alpha \frac{\partial \theta}{\partial z'} = 0$$
 (3.99)

$$\frac{\partial^2 \psi'_z}{\partial x'^2} + \frac{Da_y}{Da_x} \frac{\partial^2 \psi'_z}{\partial y'^2} + \frac{\partial^2 \psi'_z}{\partial z'^2} + (\frac{Da_y}{Da_x} - 1) \frac{\partial^2 \psi'_y}{\partial y' \partial z'} - Ra Da_y \cos \alpha \frac{\partial \theta}{\partial y'} = 0 \quad (3.100)$$

Where Da_x , Da_y , Da_z are Darcy numbers in the x, y, z direction

$$Da_x = \frac{\kappa_x}{\kappa_0^2} \tag{3.101}$$

$$Da_y = \frac{\kappa_y}{\kappa_0^2} \tag{3.102}$$

$$Da_z = \frac{\kappa_z}{\kappa_0^2} \tag{3.103}$$

and Ra is the Rayleigh number defined below

$$Ra = \frac{g \beta_0 x_0^3 (T_h - T_c) \rho_0 (\rho_0 C_p)_f}{\mu k_{eff}}$$
(3.104)

In general, $\alpha \neq 0$, and the container is not on a horizontal plane, none of the edges is along the gravity direction and we have a general non-dimensional format for the vector potentials:

$$\frac{\partial^{2} \psi'_{x}}{\partial x^{/2}} + \frac{\partial^{2} \psi'_{x}}{\partial y^{/2}} + \frac{Da_{z}}{Da_{y}} \frac{\partial^{2} \psi'_{x}}{\partial z^{/2}} + (1 - \frac{Da_{z}}{Da_{y}}) \frac{\partial^{2} \psi'_{z}}{\partial x^{/2} z^{/2}} + RaDa_{z} (\cos \gamma \frac{\partial \theta}{\partial y^{/2}} - \cos \beta \frac{\partial \theta}{\partial z^{/2}}) = 0$$
(3.105)

$$\frac{\partial^{2} \psi'_{y}}{\partial x^{/2}} + \frac{\partial^{2} \psi'_{y}}{\partial y^{/2}} + \frac{Da_{z}}{Da_{x}} \frac{\partial^{2} \psi'_{y}}{\partial z^{/2}} + (1 - \frac{Da_{z}}{Da_{x}}) \frac{\partial^{2} \psi'_{z}}{\partial y^{/} \partial z^{/}} + Ra Da_{z} (\cos \alpha \frac{\partial \theta}{\partial z^{/}} - \cos \gamma \frac{\partial \theta}{\partial x^{/}}) = 0$$
(3.106)

$$\frac{\partial^{2} \psi'_{z}}{\partial x^{/2}} + \frac{Da_{y}}{Da_{x}} \frac{\partial^{2} \psi'_{z}}{\partial y^{/2}} + \frac{\partial^{2} \psi'_{z}}{\partial z^{/2}} + (\frac{Da_{y}}{Da_{x}} - 1) \frac{\partial^{2} \psi'_{y}}{\partial y^{/} \partial z^{/}} - Ra Da_{y} (\cos \beta \frac{\partial \theta}{\partial x^{/}} - \cos \alpha \frac{\partial \theta}{\partial y^{/}}) = 0$$
(3.107)

3.9 Nusselt Number

As to the definition of Nusselt number, Nusselt number is equal to the dimensionless temperature gradient at the surface of the container. It provides of measure of the convection heat transfer occurring at the surface.

The local Nu numbers were defined as follows on the six surfaces of the container:

$$x' = 0: Nu = -\frac{\partial \theta}{\partial x'}\Big|_{x'=0} (3.108)$$

$$x' = 1: Nu = \frac{\partial \theta}{\partial x'} \Big|_{x'=1} (3.109)$$

$$y' = 0: Nu = -\frac{\partial \theta}{\partial y'}\Big|_{y'=0} (3.110)$$

$$y' = 1: Nu = \frac{\partial \theta}{\partial y'} \Big|_{y'=1} (3.111)$$

$$z' = 0: Nu = -\frac{\partial \theta}{\partial z'}\Big|_{z'=0} (3.112)$$

$$z' = 1: Nu = \frac{\partial \theta}{\partial z'}\Big|_{z'=1} (3.113)$$

The average Nusselt numbers on side-walls and top and bottom were defined as follows: on top x' = 0 and bottom $x' = x_0'$

$$Nu_{average} = \frac{1}{y'_0 z'_0} \int_0^{y'_0} \int_0^{z'_0} Nu(y', z') dy' d'z'$$
 (3.114)

on side walls y' = 0 and $y' = y_0'$

$$Nu_{average} = \frac{1}{x'_0 z'_0} \int_0^{x'_0} \int_0^{z'_0} Nu(x', z') dx' d'z'$$
 (3.115)

on side walls z' = 0 and $z' = z_0'$

$$Nu_{average} = \frac{1}{x'_0 y'_0} \int_0^{x'_0} \int_0^{y'_0} Nu(x', y') dx'd'y'$$
 (3.116)

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CHAPTER 4

NUMERICAL METHODS

4.1 Introduction

Equations (3.97), (3.105), (3.106) and (3.107) must be solved numerically. They are coupled, second-order partial differential equations, and to date it has not proved possible to obtain their exact mathematical solutions. In this chapter the numerical methods used to solve them are described.

If ψ_x , ψ_y and ψ_z are known then we can obtain velocity field via equation (3.46a). By using the known velocity field and solving equation (3.97), temperature field can be found. This is one complete iterative step in the main loop or called outer iteration. We can also revise the solution procedure by solving temperature field first and them update velocity field, but the result is the same. When one iterative step is completed, the new values of vector potentials and temperature can then be used as the starting state for the next iteration step. The iteration loop continue until the desire iteration number is reached or the solution is convergent.

Inside the main loop, two important procedures are defined as solving the vector potential field to obtain velocity field and solving temperature field. The former is more complicated than the latter.

The component equations of vector potential, equations (3.105), (3.106) and (3.107) are elliptic and coupled. The iterative loop for solving the vector potential is called the inner iterative loop. Inside the inner loop, firstly ψ_x and ψ_y are advanced by using the old ψ_z value, then the inner iteration advanced for solving ψ_z . Updated values of ψ_x , ψ_y and ψ_z can be used in the next iteration. The iteration will continue until the solutions of ψ_x , ψ_y and ψ_z cease to change significantly. We term these results the false steady state of vector potential within one outer iteration step. Because actually they are the real transient vector potential field which represents the real transient velocity field, however from the mathematical viewpoint we can imagine that we are solving a set of coupled elliptic partial differential equations which have an initial state and a final steady state. The initial state is known from the updated value of the outer iteration loop. Then the inner iteration is carried out until the final state is reached. This is the so-called steady state.

A third-level iteration loop is used for solving a single component of vector potential. We applied the false transient technique, after Mallinson and de Vahl Davis (1973), to improve the rate of convergence. The above multi-iteration scheme was employed to determine the solution of equations (3.105) to (3.107). The third-level iteration was used for solving the single component equation of vector potential. The inner iteration was used for updating the new vector potential field in which its three component equations are coupled, and the outer loop was used to obtain transient velocity field and temperature fields. A non-uniform central differential approximation was applied to obtain the differential equations, which were solved by the Samarskii-Androyev alterative direction implicit scheme.

4.2 The Approximation of Derivatives by Finite Differences

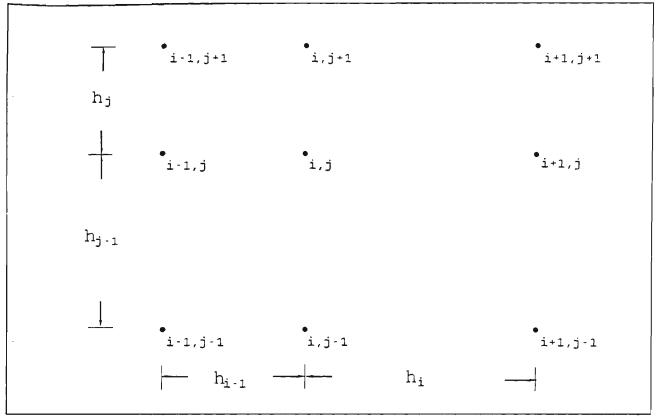


Figure 4.1 Arrangement of grid points

A non-uniform mesh was used and is shown in Figure 4.1, h_i represents the distance between (i-1)th point and ith point along the x axis, as were h_j , h_k respectively. x_i was the ith point position in x direction, so we have

$$h_i = x_i - x_{i-1} \tag{4.1}$$

$$h_j = y_j - y_{j-1} (4.2)$$

$$h_k = z_k - z_{k-1} \tag{4.3}$$

A notation to indicate the value of θ or ψ at the *pth* time step and the position in the system was adopted as follows,

$$\theta = \theta_{i,j,k}^n \tag{4.4}$$

where p, i, j, and k were default values and are not shown, hence

$$\theta_{i-1,j,k+1}^{p+1}$$
 or $\theta_{i-1,k+1}^{p+1}$ (4.5)

denotes the dimensionless temperature at the position in space $x_i h_i$, y_j , $z_k + h_i$ and at time $t + \Delta t$. The indices i, j, and k as used here will always denote position in space and the superscript p will denote time.

The space point (x_i, y_j, z_k) , also called the grid-point (i, j, k) was surrounded by neighbouring grid points shown in Figure 4.1. Assuming that the function θ , ψ possesses a sufficient number of partial derivatives. The value of them, for example, θ , at the two points, say, (x_k, y_p, z_k) and (x_{i+1}, y_p, z_k) are related by Taylor's expansion:

$$\theta_{i+1,j,k} = \theta_{i,j,k} + h_{i+1} \frac{\partial \theta}{\partial x} \Big|_{i,j,k} + \frac{1}{2!} h_{i+1}^2 \frac{\partial^2 \theta}{\partial x^2} \Big|_{i,j,k} + O(h_{i+1}^2)$$
 (4.6)

Dropping the remainder term $O(h_i^2)$ and expanding in Taylor's series for θ_{i-1} and θ_{i+1} about the central value $\theta_{i,j,k}$, we obtain

$$\theta_{i-1} = \theta - h_i \frac{\partial \theta}{\partial x} \Big|_{i,j,k} + \frac{1}{2} h_i^2 \frac{\partial^2 \theta}{\partial x^2} \Big|_{i,j,k}$$
(4.7)

$$\theta_{i+1} = \theta + h_{i+1} \frac{\partial \theta}{\partial x} \Big|_{i,j,k} + \frac{1}{2} h_{i+1}^2 \frac{\partial^2 \theta}{\partial x^2} \Big|_{i,j,k}$$
 (4.8)

From these two relations it is easy to show that

$$\left. \frac{\partial \theta}{\partial x} \right|_{i,j,k} = -\frac{h_{i+1}^2}{h_i h_{i+1} (h_i + h_{i+1})} \theta_{i-1} + \frac{h_{i+1}^2 - h_i^2}{h_i h_{i+1} (h_i + h_{i+1})} \theta + \frac{h_i^2}{h_i h_{i+1} (h_i + h_{i+1})} \theta_{i+1}$$
(4.9)

setting

$$CXI(i) = -\frac{h_{i+1}^2}{h_i h_{i+1} (h_i + h_{i+1})}$$
(4.10a)

$$CX2(i) = \frac{h_{i+1}^2 - h_i^2}{h_i h_{i+1} (h_i + h_{i+1})}$$
(4.10b)

$$CX3(i) = \frac{h_i^2}{h_i h_{i+1} (h_i + h_{i+1})}$$
 (4.10c)

we have

$$\frac{\partial \theta}{\partial x}\Big|_{i,j,k} = CXI(i)\theta_{i-1} + CX2(i)\theta + CX3(i)\theta_{i+1}$$
 (4.10)

Similarly, we find

$$\left. \frac{\partial^2 \theta}{\partial x^2} \right|_{i,j,k} = CX4(i)\theta_{i-1} + CX5(i)\theta + CX6(i)\theta_{i+1}$$
 (4.11)

where:

$$CX4(i) = \frac{2h_{i+1}}{h_i h_{i+1} (h_i + h_{i+1})}$$
(4.11a)

$$CX5(i) = -\frac{2(h_i + h_{i+1})}{h_i h_{i+1} (h_i + h_{i+1})}$$
(4.11b)

$$CX6(i) = \frac{2h_i}{h_i h_{i+1} (h_i + h_{i+1})}$$
(4.11c)

Applying the same procedure to the y and z directions we obtain

$$\left. \frac{\partial \theta}{\partial y} \right|_{i,j,k} = CYI(j)\theta_{j-1} + CY2(j)\theta + CY3(j)\theta_{j+1}$$
 (4.12)

$$CYI(j) = -\frac{h_{j+1}^2}{h_j h_{j+1} (h_j + h_{j+1})}$$
 (4.12a)

$$CY2(j) = \frac{h_{j+1}^2 - h_j^2}{h_j h_{j+1} (h_j + h_{j+1})}$$
(4.12b)

$$CY3(j) = \frac{h_j^2}{h_j h_{j+1} (h_j + h_{j+1})}$$
 (4.12c)

$$\left. \frac{\partial^2 \theta}{\partial y^2} \right|_{i,j,k} = CY4(j)\theta_{j-1} + CY5(j)\theta + CY6(j)\theta_{j+1}$$
 (4.13)

$$CY4(j) = \frac{2h_{j+1}}{h_j h_{j+1} (h_j + h_{j+1})}$$
(4.13a)

$$CY5(j) = -\frac{2(h_j + h_{j+1})}{h_j h_{j+1} (h_j + h_{j+1})}$$
(4.13b)

$$CY6(j) = \frac{2 h_j}{h_j h_{j+1} (h_j + h_{j+1})}$$
 (4.13c)

$$\frac{\partial \theta}{\partial z}\Big|_{i,j,k} = CZI(k)\theta_{k-1} + CZ2(k)\theta + CZ3(k)\theta_{k+1}$$
 (4.14)

$$CZI(k) = -\frac{h_{k+1}^2}{h_k h_{k+1} (h_k + h_{k+1})}$$
(4.14a)

$$CZ2(k) = \frac{h_{k+1}^2 - h_k^2}{h_k h_{k+1} (h_k + h_{k+1})}$$
(4.14b)

$$CZ3(k) = \frac{h_k^2}{h_k h_{k+1} (h_k + h_{k+1})}$$
 (4.14c)

$$\left. \frac{\partial^2 \theta}{\partial z^2} \right|_{i,j,k} = CZ4(k)\theta_{k-1} + CZ5(k)\theta + CZ6(k)\theta_{k+1}$$
 (4.15)

$$CZ4(k) = \frac{2 h_{k+1}}{h_k h_{k+1} (h_k + h_{k+1})}$$
 (4.15a)

$$CZ5(k) = -\frac{2(h_k + h_{k+1})}{h_k h_{k+1} (h_k + h_{k+1})}$$
(4.15b)

$$CZ6(k) = \frac{2 h_k}{h_k h_{k+1} (h_k + h_{k+1})}$$
 (4.15c)

There are second-order partial differences in the equations (3.98), (3.99) and (3.100). To derive their finite difference approximations, we applied Taylor's expansion on the grid points as shown in Figure 4.1, we obtain

$$\psi_{i+1, j+1} = \psi_{i+1, j} + h_j \frac{\partial \psi}{\partial y} \Big|_{i+1, j} + \frac{h_j^2}{2} \frac{\partial^2 \psi}{\partial y^2} \Big|_{i+1, j}$$
(4.16)

$$\Psi_{i+1, j-1} = \Psi_{i+1, j} - h_{j-1} \frac{\partial \Psi}{\partial y} \Big|_{i+1, j} + \frac{h_{j-1}^2}{2} \frac{\partial^2 \Psi}{\partial y^2} \Big|_{i+1, j}$$
(4.17)

$$\psi_{i-1, j+1} = \psi_{i-1, j} + h_j \frac{\partial \psi}{\partial y} \Big|_{i-1, j} + \frac{h_j^2}{2} \frac{\partial^2 \psi}{\partial y^2} \Big|_{i-1, j}$$
(4.18)

$$\psi_{i-1, j-1} = \psi_{i-1, j} - h_{j-1} \frac{\partial \psi}{\partial y} \Big|_{i-1, j} + \frac{h_{j-1}^2}{2} \frac{\partial^2 \psi}{\partial y^2} \Big|_{i-1, j}$$
(4.19)

Eq. (4.16) $*h_{j-1}^2 - Eq. (4.17) *h_j^2$, we have

$$\psi_{i+1,j+1}h_{j-1}^{2} - \psi_{i+1,j-1}h_{j}^{2} = (h_{j-1}^{2} - h_{j}^{2})\psi_{i+1,j} + (h_{j}h_{j-1}^{2} + h_{j}^{2}h_{j-1})\frac{\partial\psi}{\partial y}\Big|_{i+1,j}$$
(4.20)

Eq. (4.18) $*h_{i-1}^2 - Eq. (4.19) *h_i^2$, we have

$$\psi_{i-1,j+1} h_{j-1}^{2} - \psi_{i-1,j-1} h_{j}^{2} = (h_{j-1}^{2} - h_{j}^{2}) \psi_{i-1,j} + (h_{j} h_{j-1}^{2} + h_{j}^{2} h_{j-1}) \frac{\partial \psi}{\partial v}\Big|_{i-1,j}$$
(4.21)

Using Taylor's expansion, we obtain

$$\frac{\partial \psi}{\partial y}\Big|_{i+1,j} = \frac{\partial \psi}{\partial y} + h_i \frac{\partial^2 \psi}{\partial x \, \partial y} + \frac{h_i^2}{2} \frac{\partial^3 \psi}{\partial y \, \partial x^2}$$
(4.22)

$$\frac{\partial \psi}{\partial y}\Big|_{i-1,j} = \frac{\partial \psi}{\partial y} - h_{i-1} \frac{\partial^2 \psi}{\partial x \partial y} + \frac{h_{i-1}^2}{2} \frac{\partial^3 \psi}{\partial y \partial x^2}$$
(4.23)

By using equations (4.20), (4.21), (4.22) and (4.23), and eliminating $\frac{\partial^3 \psi}{\partial y \partial x^2}$, we get

$$h_{i-1}^{2} (\psi_{i+1,j+1} h_{j-1}^{2} - \psi_{i+1,j-1} h_{j}^{2}) - h_{i}^{2} (\psi_{i-1,j+1} h_{j-1}^{2} - \psi_{i-1,j-1} h_{j}^{2})$$

$$= (h_{j-1}^{2} - h_{j}^{2}) h_{i-1}^{2} \psi_{i+1,j} - (h_{j-1}^{2} - h_{j}^{2}) h_{i}^{2} \psi_{i-1,j}$$

$$+ (h_{i-1}^{2} - h_{i}^{2}) (h_{j} h_{j-1}^{2} + h_{j}^{2} h_{j-1}) \frac{\partial \psi}{\partial y}$$

$$+ (h_{j} h_{j-1}^{2} + h_{j} h_{j-1}^{2}) (h_{i-1}^{2} h_{i} + h_{i}^{2} h_{i-1}) \frac{\partial^{2} \psi}{\partial x \partial y}$$

$$(4.24)$$

By using equation (4.12) to find the differential expression for $\frac{\partial \psi}{\partial y}$, finally we obtain the differential expression as:

$$\frac{\partial^{2} \psi}{\partial x \, \partial y} = CXMIYMI(i,j) \psi_{i-1,j-1} + CXYMI(i,j) \psi_{i,j-1} + CXPIYMI(i,j) \psi_{i+1,j-1}
+ CXMIY(i,j) \psi_{i-1,j} + CXY \psi_{i,j} + CXPIY(i,j) \psi_{i+1,j}
+ CXMIYPI(i,j) \psi_{i-1,j+1} + CXYPI(i,j) \psi_{i,j+1} + CXPIYPI(i,j) \psi_{i+1,j+1}
(4.25)$$

$$CXMIYMI(i,j) = \frac{h_i^2 h_j^2}{DENOM1}$$
 (4.25a)

$$CXYM1(i,j) = \frac{DENOM2 * h_j^2}{DENOM1 * DENOM3}$$
(4.25b)

$$CXPIYM1(i,j) = -\frac{h_{i-1}^2 h_j^2}{DENOM1}$$
 (4.25c)

$$CXMIY(i,j) = \frac{h_i^2(h_{j-1}^2 - h_j^2)}{DENOM1}$$
 (4.25d)

$$CXY(i,j) = -\frac{DENOM2 * (h_j^2 - h_{j-1}^2)}{DENOM1 * DENOM3}$$
 (4.25e)

$$CXPIY(i,j) = -\frac{h_{i-1}^{2}(h_{j-1}^{2} - h_{j}^{2})}{DENOM1}$$
(4.25f)

$$CXM1YP1(i,j) = -\frac{h_i^2 h_{j-1}^2}{DENOM1}$$
 (4.25g)

$$CXYP1(i,j) = -\frac{DENOM2 * h_{j-1}^2}{DENOM1 * DENOM3}$$
(4.25h)

$$CXPIYPI(i,j) = \frac{h_{i-1}^2 h_{j-1}^2}{DENOM1}$$
 (4.25i)

$$DENOM1 = (h_{j-1}^2 h_j + h_{j-1} h_j^2) (h_{i-1}^2 h_i + h_{i-1} h_i^2)$$
 (4.25j)

$$DENOM2 = (h_{i-1}^2 h_i + h_{i-1} h_i^2) (h_{i-1}^2 - h_i^2)$$
 (4.25k)

$$DENOM3 = h_{i-1} h_i (h_{i-1} + h_i)$$
 (4.25m)

Similarly we can obtain differential expressions for $\frac{\partial^2 \psi}{\partial x \partial z}$, $\frac{\partial^2 \psi}{\partial y \partial z}$.

4.3 Finite Differences Approximations on Boundary

We can not use the above differences equations to determine the values on the boundary because they are derived for a central point which relies on values on both sides of the point. The values of the point outside the boundary are unknown so the central point can not be determined by using this method.

4.3.1 Finite Difference Formulas for the First-Order Derivatives on Boundaries for Energy Equation

There were only first-order derivatives in the boundary conditions, refer to the boundary

conditions for energy equation.

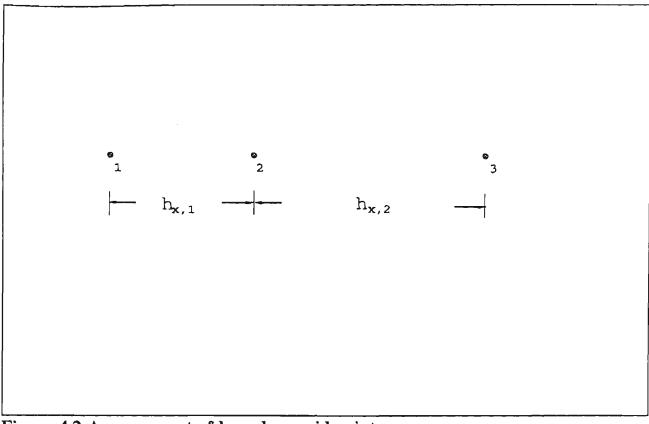


Figure 4.2 Arrangement of boundary grid points

For the low limit, ie x=0, as shown in Figure 4.2, we have

$$\theta_{2,j,k} = \theta_{1,j,k} + h_{x,1} \frac{\partial \theta}{\partial x} \Big|_{1,j,k} + \frac{h_{x,1}^2}{2} \frac{\partial^2 \theta}{\partial x^2} \Big|_{1,j,k}$$
(4.26)

$$\theta_{3j,k} = \theta_{1j,k} + (h_{x,1} + h_{x,2}) \frac{\partial \theta}{\partial x} \Big|_{1,j,k} + \frac{(h_{x,1} + h_{x,2})^2}{2} \frac{\partial^2 \theta}{\partial x^2} \Big|_{1,j,k}$$
(4.27)

by eliminating the second-order derivative, we obtain

$$\frac{\partial \theta}{\partial x}\Big|_{1,j,k} = CX1TL\,\theta_{1,j,k} + CX2TL\,\theta_{2,j,k} + CX3TL\,\theta_{3,j,k} \tag{4.28}$$

$$CXITL = -\frac{(h_{x,1} + h_{x,2})^2 - h_{x,1}^2}{h_{x,1}(h_{x,1} + h_{x,2})^2 - h_{x,1}^2(h_{x,1} + h_{x,2})}$$
(4.28a)

$$CX2TL = \frac{(h_{x,1} + h_{x,2})^2}{h_{x,1}(h_{x,1} + h_{x,2})^2 - h_{x,1}^2(h_{x,1} + h_{x,2})}$$
(4.28b)

$$CX3TL = -\frac{h_{x,1}^2}{h_{x,1}(h_{x,1} + h_{x,2})^2 - h_{x,1}^2(h_{x,1} + h_{x,2})}$$
(4.28c)

Similarly we can obtain derivatives for the high limit in the x direction and those for y, z axis as follows:

$$\left. \frac{\partial \theta}{\partial x} \right|_{NX,j,k} = CX1TH \, \theta_{NX,j,k} + CX2TH \, \theta_{NX-1,j,k} + CX3TH \, \theta_{NX-2,j,k} \tag{4.29}$$

where

$$CXITH = \frac{(h_{x,NX-1} + h_{x,NX-2})^2 - h_{x,NX-1}^2}{h_{x,NX-1}(h_{x,NX-1} + h_{x,NX-2})^2 - h_{x,NX-1}^2(h_{x,NX-1} + h_{x,NX-2})}$$
(4.29a)

$$CX2TH = -\frac{(h_{x,NX-1} + h_{x,NX-2})^2}{h_{x,NX-1}(h_{x,NX-1} + h_{x,NX-2})^2 - h_{x,NX-1}^2(h_{x,NX-1} + h_{x,NX-2})}$$
(4.29b)

$$CX3TH = \frac{h_{x,NX-1}^2}{h_{x,NX-1}(h_{x,NX-1} + h_{x,NX-2})^2 - h_{x,NX-1}^2(h_{x,NX-1} + h_{x,NX-2})}$$
(4.29c)

$$\left. \frac{\partial \theta}{\partial y} \right|_{i,1,k} = CYITL \theta_{i,1,k} + CY2TL \theta_{i,2,k} + CY3TL \theta_{i,3,k}$$
 (4.30)

$$CYITL = -\frac{(h_{y,1} + h_{y,2})^2 - h_{y,1}^2}{h_{y,1}(h_{y,1} + h_{y,2})^2 - h_{y,1}^2(h_{y,1} + h_{y,2})}$$
(4.30a)

$$CY2TL = \frac{(h_{y,1} + h_{y,2})^2}{h_{y,1}(h_{y,1} + h_{y,2})^2 - h_{y,1}^2(h_{y,1} + h_{y,2})}$$
(4.30b)

$$CY3TL = -\frac{h_{y,1}^2}{h_{y,1}(h_{y,1} + h_{y,2})^2 - h_{y,1}^2(h_{y,1} + h_{y,2})}$$
(4.30c)

$$\frac{\partial \theta}{\partial y}\Big|_{i,NY,k} = CY1TH \,\theta_{i,NY,k} + CY2TH \,\theta_{i,NY-1,k} + CY3TH \,\theta_{i,NY-2,k} \tag{4.31}$$

where

$$CYITH = \frac{(h_{y,NY-1} + h_{y,NY-2})^2 - h_{y,NY-1}^2}{h_{y,NY-1}(h_{y,NY-1} + h_{y,NY-2})^2 - h_{y,NY-1}^2(h_{y,NY-1} + h_{y,NY-2})}$$
(4.31a)

$$CY2TH = -\frac{(h_{y,NY-1} + h_{y,NY-2})^2}{h_{y,NY-1}(h_{y,NY-1} + h_{y,NY-2})^2 - h_{y,NY-1}^2(h_{y,NY-1} + h_{y,NY-2})}$$
(4.31b)

$$CY3TH = \frac{h_{y,NY-1}^2}{h_{y,NY-1}(h_{y,NY-1} + h_{y,NY-2})^2 - h_{y,NY-1}^2(h_{y,NY-1} + h_{y,NY-2})}$$
(4.31c)

$$\frac{\partial \theta}{\partial z}\Big|_{i,j,1} = CZ1TL \,\theta_{i,j,1} + CZ2TL \,\theta_{i,j,2} + CZ3TL \,\theta_{i,j,3} \tag{4.32}$$

where

$$CZITL = -\frac{(h_{z,1} + h_{z,2})^2 - h_{z,1}^2}{h_{z,1}(h_{z,1} + h_{z,2})^2 - h_{z,1}^2(h_{z,1} + h_{z,2})}$$
(4.32a)

$$CZ2TL = \frac{(h_{z,1} + h_{z,2})^2}{h_{z,1}(h_{z,1} + h_{z,2})^2 - h_{z,1}^2(h_{z,1} + h_{z,2})}$$
(4.32b)

$$CZ3TL = -\frac{h_{z,1}^2}{h_{z,1}(h_{z,1} + h_{z,2})^2 - h_{z,1}^2(h_{z,1} + h_{z,2})}$$
(4.32c)

$$\frac{\partial \theta}{\partial z}\Big|_{i,j,NZ} = CZITH \theta_{i,j,NZ} + CZ2TH \theta_{i,j,NZ-1} + CZ3TH \theta_{i,j,NZ-2}$$
(4.33)

$$CZ1TH = \frac{(h_{z,NZ-1} + h_{z,NZ-2})^2 - h_{z,NZ-1}^2}{h_{z,NZ-1}(h_{z,NZ-1} + h_{z,NZ-2})^2 - h_{z,NZ-1}^2(h_{z,NZ-1} + h_{z,NZ-2})}$$
(4.33a)

$$CZ2TH = -\frac{(h_{z,NZ-1} + h_{z,NZ-2})^2}{h_{z,NZ-1}(h_{z,NZ-1} + h_{z,NZ-2})^2 - h_{z,NZ-1}^2(h_{z,NZ-1} + h_{z,NZ-2})}$$
(4.33b)

$$CZ3TH = \frac{h_{z,NZ-1}^2}{h_{z,NZ-1}(h_{z,NZ-1} + h_{z,NZ-2})^2 - h_{z,NZ-1}^2(h_{z,NZ-1} + h_{z,NZ-2})}$$
(4.33c)

4.3.2 Finite Difference Formulas for the Second-Order Derivatives on Boundaries for $\boldsymbol{\psi}$

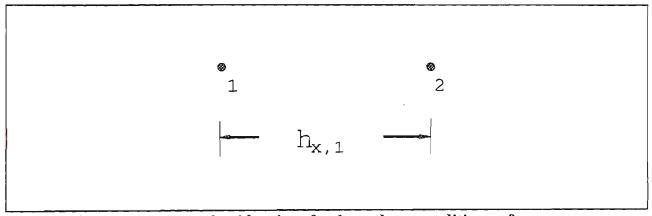


Figure 4.3 Arrangement of grid points for boundary conditions of ψ

The finite difference formulas on boundaries for ψ are quite simple because at the boundary the first derivatives vanish. Using Taylor's series, we have the following relation for the lower limit boundary as illustrated in Figure 4.3.

$$\psi_{x,2} = \psi_{x,1} + \frac{h_{x,1}^2}{2} \frac{\partial^2 \psi}{\partial x^2} \Big|_{1,j,k}$$
 (4.34)

We define

$$\left. \frac{\partial^2 \psi}{\partial x^2} \right|_{1,j,k} = CX5PL \psi_{x,1} + CX6PL \psi_{x,2} \tag{4.35}$$

$$CX5PL = -\frac{2}{h_{x,1}^2} \tag{4.35a}$$

$$CX6PL = \frac{2}{h_{x,1}^2}$$
 (4.35b)

Similarly we can find the approximations for the higher limit side for the x direction and those for y and z axes.

$$\frac{\partial^2 \psi}{\partial x^2}\bigg|_{NX,J,k} = CX4PH \psi_{x,NX-1} + CX5PH \psi_{x,NX-2}$$
 (4.36)

where

$$CX4PH = \frac{2}{h_{x,NX-1}^2}$$
 (4.36a)

$$CX5PH = -\frac{2}{h_{x,NX-1}^2}$$
 (4.36b)

$$\left. \frac{\partial^2 \psi}{\partial y^2} \right|_{i,1,k} = CY5PL \psi_{y,1} + CY6PL \psi_{y,2} \tag{4.37}$$

where

$$CY5PL = -\frac{2}{h_{y,1}^2} (4.37a)$$

$$CY6PL = \frac{2}{h_{y,1}^2} \tag{4.37b}$$

$$\left. \frac{\partial^2 \psi}{\partial y^2} \right|_{i,NY,k} = CY4PH \psi_{y,NY-1} + CY5PH \psi_{y,NY-2} \tag{4.38}$$

where

$$CY4PH = \frac{2}{h_{y,NY-1}^2}$$
 (4.38a)

$$CY5PH = -\frac{2}{h_{y,NY-1}^2}$$
 (4.38b)

$$\left. \frac{\partial^2 \psi}{\partial z^2} \right|_{i,j,1} = CZ5PL \psi_{z,1} + CZ6PL \psi_{z,2} \tag{4.39}$$

$$CZ5PL = -\frac{2}{h_{z,1}^2} \tag{4.39a}$$

$$CZ6PL = \frac{2}{h_{z,1}^2} \tag{4.39b}$$

$$\left. \frac{\partial^2 \psi}{\partial z^2} \right|_{i,j,NZ} = CZ4PH \psi_{z,NZ-1} + CZ5PH \psi_{z,NZ-2}$$
 (4.40)

where

$$CZAPH = \frac{2}{h_{z,NZ-1}^2}$$
 (4.40a)

$$CZ5PH = -\frac{2}{h_{z,NZ-1}^2}$$
 (4.40b)

4.4 The False Transient Equations of Vector Potential

The method of false transient makes two simple changes to each vector potential component equation: a fictitious transient term is inserted in the left side of the equations and the time derivatives are given modified coefficients. Equations (3.105), (3.106) and (3.107) become:

$$\frac{1}{\alpha_{\psi}} \frac{\partial \psi_{x}^{\prime}}{\partial t^{\prime}} = \frac{\partial^{2} \psi_{x}^{\prime}}{\partial x^{\prime 2}} + \frac{\partial^{2} \psi_{x}^{\prime}}{\partial y^{\prime 2}} + \frac{Da_{z}}{Da_{y}} \frac{\partial^{2} \psi_{x}^{\prime}}{\partial z^{\prime 2}} + (1 - \frac{Da_{z}}{Da_{y}}) \frac{\partial^{2} \psi_{z}^{\prime}}{\partial x^{\prime} \partial z^{\prime}} + RaDa_{z}(\cos \gamma \frac{\partial \theta}{\partial y^{\prime}} - \cos bata \frac{\partial \theta}{\partial z^{\prime}})$$
(4.41)

$$\frac{1}{\alpha_{\psi}} \frac{\partial \psi_{y}^{\prime}}{\partial t^{\prime}} = \frac{\partial^{2} \psi_{y}^{\prime}}{\partial x^{\prime 2}} + \frac{\partial^{2} \psi_{y}^{\prime}}{\partial y^{\prime 2}} + \frac{Da_{z}}{Da_{x}} \frac{\partial^{2} \psi_{y}^{\prime}}{\partial z^{\prime 2}} + (1 - \frac{Da_{z}}{Da_{x}}) \frac{\partial^{2} \psi_{z}^{\prime}}{\partial y^{\prime} \partial z^{\prime}} + RaDa_{z} (\cos \alpha \frac{\partial \theta}{\partial z^{\prime}} - \cos \gamma \frac{\partial \theta}{\partial x^{\prime}})$$
(4.42)

$$\frac{1}{\alpha_{\psi}} \frac{\partial \psi_{z}^{\prime}}{\partial t^{\prime}} = \frac{\partial^{2} \psi_{z}^{\prime}}{\partial x^{\prime 2}} + \frac{Da_{y}}{Da_{x}} \frac{\partial^{2} \psi_{z}^{\prime}}{\partial y^{\prime 2}} + \frac{\partial^{2} \psi_{z}^{\prime}}{\partial z^{\prime 2}} + (\frac{Da_{y}}{Da_{x}} - 1) \frac{\partial^{2} \psi_{y}^{\prime}}{\partial y^{\prime} \partial z^{\prime}} + RaDa_{y}(\cos \beta \frac{\partial \theta}{\partial x^{\prime}} - \cos \alpha \frac{\partial \theta}{\partial y^{\prime}})$$
(4.43)

If such a "steady state" solution exists, clearly the left hand side of equations (4.41), (4.42) and (4.43) will be zero and the results for them are identified as being the same as solved from equations (3.105), (3.106), (3.107).

The introduction of false transient coefficients α_{ψ} enhance the rate of convergence by setting different value of α_{ψ} , therefore the steady state ψ can be obtained more efficiently.

4.5 The Iteration Scheme for a Single Equation - Samarskii-Andreyev Implicit Alternating Direction Method.

Equations (3.93), (4.41), (4.42) and (4.43) have four independent variables x,y,z and time t. In this study an implicit alternating-direction methods - the Samarskii- Andreyev (1963) Scheme was employed. It is also called the locally-one dimensional method because each equation is split into three one-dimensional equations to be solved at each stage of the solution.

4.5.1 Solution Procedure of Vector Potential

4.5.1.1 Solution of X Component ψ_x

$$\frac{1}{\alpha_{\psi}} \frac{\partial \psi_{x}^{\prime}}{\partial t^{\prime}} = \frac{\partial^{2} \psi_{x}^{\prime}}{\partial x^{\prime 2}} + \frac{\partial^{2} \psi_{x}^{\prime}}{\partial y^{\prime 2}} + \frac{Da_{z}}{Da_{y}} \frac{\partial^{2} \psi_{x}^{\prime}}{\partial z^{\prime 2}} + (1 - \frac{Da_{z}}{Da_{y}}) \frac{\partial^{2} \psi_{z}^{\prime}}{\partial x^{\prime} \partial z^{\prime}} + RaDa_{z} (\cos \gamma \frac{\partial \theta}{\partial y^{\prime}} - \cos \beta \frac{\partial \theta}{\partial z^{\prime}})$$
(4.41)

We define intermediate variable ω as

$$\omega = \frac{1}{\alpha_w} \frac{\partial \psi_x'}{\partial t'} \tag{4.44}$$

and

$$\psi_x' = \alpha_{yy} \delta \Delta t' \omega + \psi_x'^{p} \tag{4.45}$$

implicit in
$$x$$
 direction:

$$\omega^* = \frac{\partial^2}{\partial x'^2} (\alpha_{\psi} \delta \Delta t' \omega^* + \psi_x'^p) + \frac{\partial^2 \psi_x'}{\partial y'} + \frac{Da_z}{Da_y} \frac{\partial^2 \psi_x'}{\partial z'} + (1 - \frac{Da_z}{Da_y}) \frac{\partial^2 \psi_z'}{\partial x' \partial z'} + Ra Da_z (\cos \gamma \frac{\partial \theta}{\partial y'} - \cos \beta \frac{\partial \theta}{\partial z'})$$
(4.46)

Using differential approximations, the above expression can be expanded to:

$$\omega^{*} - \alpha_{\psi} \delta \Delta t' (CX4(i) \omega_{i-1}^{*} + CX5(i) \omega^{*} + CX6(i) \omega_{i+1}^{*}) \\
= CX4(i) \psi_{x, i-1}' + CX5(i) \psi_{x}' + CX6(i) \psi_{x, i+1}' \\
+ CY4(j) \psi_{x, j-1}' + CY5(j) \psi_{x}' + CY6(j) \psi_{x, j+1}' \\
+ \frac{Da_{z}}{Da_{y}} (CZ4(k) \psi_{x, k-1}' + CZ5(k) \psi_{x}' + CZ6(k) \psi_{x, k+1}') \\
+ (1 - \frac{Da_{z}}{Da_{y}}) (CXM1ZM1(i, k) \psi_{z, i-1, k-1}' + CXZM1(i, k) \psi_{z, i, k-1}' \\
+ CXP1ZM1(i, k) \psi_{z, i+1, k-1}' + CXM1Z(i, k) \psi_{z, i-1, k}' + CXZ(i, k) \psi_{z, i, k}' \\
+ CXP1Z(i, k) \psi_{z, i+1, k}' + CXM1ZP1(i, k) \psi_{z, i-1, k+1}' \\
+ CXZP1(i, k) \psi_{z, i, k+1}' + CXP1ZP1(i, k) \psi_{z, i+1, k+1}' \\
+ RaDa_{z}[\cos \gamma (CY1(j) \theta_{j-1} + CY2(j) \theta + CY3(j) \theta_{j+1}) \\
- \cos \beta (CZ1(k) \theta_{k-1} + CZ2(k) \theta + CZ3(k) \theta_{k+1})]$$
(4.47)

Now we define:

$$A(I) = -\alpha_{+} \delta \Delta t' CX4(i)$$
 (4.48)

$$B(I) = -\alpha_{+} \delta \Delta t' CX5(i) + 1 \tag{4.49}$$

$$C(I) = -\alpha_{\psi} \delta \Delta t' CX6(i)$$
 (4.50)

$$D(I)=RHS$$
 of above equation (4.51)

Simplifying the expression yields:

$$A(I)\omega_{i-1}^* + B(I)\omega_i^* + C(I)\omega_{i+1} = D(I)$$
(4.52)

We may expand equation (4.52) as

$$B(1)\omega_{1}^{*}+C(1)\omega_{2}^{*} = D(1)$$

$$A(2)\omega_{1}^{*}+B(2)\omega_{2}^{*}+C(2)\omega_{3}^{*} = D(2)$$

$$A(3)\omega_{2}^{*}+B(3)\omega_{3}^{*}+C(3)\omega_{4}^{*} = D(3)$$

$$A(NX-1)\omega_{NX-2}^{*}+B(NX-1)\omega_{NX-1}^{*}+(NX-1)\omega_{NX}^{*}=D(NX-1)$$

$$A(NX)\omega_{NX-1}^{*}+B(NX)\omega_{NX}^{*}=D(NX)$$

$$(4.53)$$

This is a tri-diagonal equation set and can be easily solved using the Thomas solution. (see Appendix B)

The second step is to implicitly advance the iteration in y direction:

$$\omega_{j}^{**} - \delta \alpha_{\psi} \Delta t' \left(CY4(j) \ \omega_{j-1}^{**} + CY5(j) \omega_{j}^{**} + CY6(j) \omega_{j+1}^{**} \right) = \omega^{*} \tag{4.54}$$

let

$$A(J) = -\alpha_{\star} \delta \Delta t' CY4(j)$$
 (4.55)

$$B(J) = -\alpha_{*} \delta \Delta t' CY5(j) + 1 \tag{4.56}$$

$$C(J) = -\alpha_{+} \delta \Delta t' CY6(j)$$
 (4.57)

$$D(J) = \omega^* \tag{4.58}$$

Thus we have:

$$A(J)\omega_{j-1}^{**} + B(J)\omega_{j}^{**} + C(J)\omega_{j+1}^{**} = D(J)$$
 (4.59)

Again this is a set of tri-diagonal equations and can be solved by the Thomas method.

The third step is to implicitly advance in the z direction:

$$\omega_{k}^{****} - \delta \alpha_{\psi} \Delta t' \frac{Da_{z}}{Da_{y}} \left(CZ4(k) \omega_{k-1}^{****} + CZ5(k) \omega_{k}^{****} + CZ6(k) \omega_{k+1}^{****} \right) = \omega^{***} (4.60)$$

$$A(K) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{z}}{Da_{y}} CZA(k)$$
 (4.61)

$$B(K) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{z}}{Da_{y}} CZS(k) + 1$$
 (4.62)

$$C(K) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{z}}{Da_{y}} CZ\delta(k)$$
 (4.63)

$$D(K) = \omega^{**} \tag{4.64}$$

By using the Thomas method, we obtain the final intermediate value of ω^{***} , the vector potential can be updated by:

$$\psi_x^{p+1} = \psi_x^p + \alpha_{\pm} \Delta t' \omega^{+++} \tag{4.65}$$

4.5.1.2 Solutions of Y Component: ψ_{ν}

$$\frac{1}{\alpha_{\psi}} \frac{\partial \psi_{y}^{\prime}}{\partial t^{\prime}} = \frac{\partial^{2} \psi_{y}^{\prime}}{\partial x^{\prime^{2}}} + \frac{\partial^{2} \psi_{y}^{\prime}}{\partial y^{\prime^{2}}} + \frac{Da_{z}}{Da_{x}} \frac{\partial^{2} \psi_{y}^{\prime}}{\partial z^{\prime^{2}}} + (1 - \frac{Da_{z}}{Da_{x}}) \frac{\partial^{2} \psi_{z}^{\prime}}{\partial y^{\prime} \partial z^{\prime}} + RaDa_{z} (\cos \alpha \frac{\partial \theta}{\partial z^{\prime}} - \cos \gamma \frac{\partial \theta}{\partial x^{\prime}})$$
(4.42)

Similar to ψ_x , we also define an intermediate variable ω as

$$\omega = \frac{1}{\alpha_{\Psi}} \frac{\partial \psi_{y}'}{\partial t'} \tag{4.66}$$

and

$$\psi_y' = \alpha_{\psi} \delta \Delta t' \omega + \psi_y'^p \tag{4.67}$$

implicit in x direction:

$$\omega^{*} = \frac{\partial^{2}}{\partial x^{/2}} (\alpha_{\psi} \delta \Delta t^{\prime} \omega^{*} + \psi_{y}^{\prime p}) + \frac{\partial^{2} \psi_{y}^{\prime}}{\partial y^{\prime}} + \frac{Da_{z}}{Da_{x}} \frac{\partial^{2} \psi_{y}^{\prime}}{\partial z^{\prime}} +$$

$$(1 - \frac{Da_{z}}{Da_{x}}) \frac{\partial^{2} \psi_{z}^{\prime}}{\partial y^{\prime} \partial z^{\prime}} + Ra Da_{z} (\cos \alpha \frac{\partial \theta}{\partial z^{\prime}} - \cos \gamma \frac{\partial \theta}{\partial x^{\prime}})$$

$$(4.68)$$

Using differential approximations, the above expression can be expanded to:

Now we define:

$$A(I) = -\alpha_{\psi} \delta \Delta t' CX4(i)$$
 (4.70)

$$B(I) = -\alpha_{+} \delta \Delta t' CX5(i) + 1 \tag{4.71}$$

$$C(I) = -\alpha_{+} \delta \Delta t' CX6(i)$$
 (4.72)

$$D(I)=RHS$$
 of above equation (4.73)

simplifying the expression we obtain

$$A(I)\omega_{i-1}^* + B(I)\omega_{i}^* + C(I)\omega_{i+1} = D(I)$$
(4.74)

Again this is a tri-diagonal equation set easily solved by the Thomas method.

The second step is to implicitly advance the iteration in the y direction:

$$\omega_{j}^{**} - \delta \alpha_{\psi} \Delta t' \left(CY4(j) \omega_{j-1}^{**} + CY5(j) \omega_{j}^{**} + CY6(j) \omega_{j+1}^{**} \right) = \omega^{*}$$
 (4.75)

$$A(J) = -\alpha_{+}\delta \Delta t' CY4(j)$$
 (4.76)

$$B(J) = -\alpha_{\pm} \delta \Delta t' CY5(j) + 1 \tag{4.77}$$

$$C(J) = -\alpha_{\psi} \delta \Delta t' CY6(j) \tag{4.78}$$

$$D(J) = \omega^* \tag{4.79}$$

Thus we have

$$A(J)\omega_{j-1}^{**} + B(J)\omega_{j}^{**} + C(J)\omega_{j+1}^{**} = D(J)$$
 (4.80)

Again this is a set of tri-diagonal equations and can be solved by the Thomas method.

The third step is to implicitly advance in z direction:

$$\omega_{k}^{***} - \delta \alpha_{\psi} \Delta t' \frac{Da_{z}}{Da_{x}} \left(CZ4(k) \omega_{k-1}^{***} + CZ5(k) \omega_{k}^{***} + CZ6(k) \omega_{k+1}^{***} \right) = \omega^{**} \quad (4.81)$$

$$A(K) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{z}}{Da_{x}} CZA(k)$$
 (4.82)

$$B(K) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{z}}{Da_{x}} CZ5(k) + 1$$
 (4.83)

$$C(K) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{z}}{Da_{x}} CZ\delta(k)$$
 (4.84)

$$D(K) = \omega^{**} \tag{4.85}$$

By using the Thomas method, we obtain the final intermediate value of ω^{**} , the vector potential can be updated by:

$$\psi_y^{p+1} = \psi_y^p + \alpha_{\psi} \Delta t' \omega^{***} \tag{4.86}$$

4.5.1.3. Solution of Z Component ψ ,

$$\frac{1}{\alpha_{\psi}} \frac{\partial \psi_{z}^{\prime}}{\partial t^{\prime}} = \frac{\partial^{2} \psi_{z}^{\prime}}{\partial x^{\prime 2}} + \frac{Da_{y}}{Da_{x}} \frac{\partial^{2} \psi_{z}^{\prime}}{\partial y^{\prime 2}} + \frac{\partial^{2} \psi_{z}^{\prime}}{\partial z^{\prime 2}} + (\frac{Da_{y}}{Da_{x}} - 1) \frac{\partial^{2} \psi_{y}^{\prime}}{\partial y^{\prime} \partial z^{\prime}} + RaDa_{y}(\cos \beta \frac{\partial \theta}{\partial x^{\prime}} - \cos \alpha \frac{\partial \theta}{\partial y^{\prime}})$$
(4.43)

We define intermediate variable ω as

$$\omega = \frac{1}{\alpha_{vir}} \frac{\partial \psi_z'}{\partial t'} \tag{4.87}$$

and

$$\psi_z' = \alpha_{yz} \delta \Delta t' \omega + \psi_z'^P \tag{4.88}$$

implicit in x direction:

$$\omega^{*} = \frac{\partial^{2}}{\partial x^{/2}} (\alpha_{\psi} \delta \Delta t^{\prime} \omega^{*} + \psi_{z}^{\prime p}) + \frac{Da_{y}}{Da_{x}} \frac{\partial^{2} \psi_{z}^{\prime}}{\partial y^{\prime}} + \frac{\partial^{2} \psi_{z}^{\prime}}{\partial z^{\prime}} + \frac{\partial^{2} \psi_{z}^{\prime}}{\partial z^{\prime}} + (\frac{Da_{y}}{Da_{x}} - 1) \frac{\partial^{2} \psi_{y}^{\prime}}{\partial y^{\prime} \partial z^{\prime}} + Ra Da_{y} (\cos \beta \frac{\partial \theta}{\partial x^{\prime}} - \cos \alpha \frac{\partial \theta}{\partial y^{\prime}})$$

$$(4.89)$$

Using differential approximations, the above expression can be expanded to:

$$\begin{split} \omega^* - \alpha_{\psi} \delta \Delta t' (CX4(i) \omega_{i-1}^* + CX5(i) \omega^* + CX6(i) \omega_{i+1}^*) \\ &= CX4(i) \psi_{z, i-1}' + CX5(i) \psi_{z}' + CX6(i) \psi_{z, i+1}' \\ &+ \frac{Da_{y}}{Da_{x}} (CY4(j) \psi_{z, j-1}' + CY5(j) \psi_{z}' + CY6(j) \psi_{z, j+1}') \\ &+ CZ4(k) \psi_{z, k-1}' + CZ5(k) \psi_{z}' + CZ6(k) \psi_{z, k+1}') \\ &+ (\frac{Da_{y}}{Da_{x}} - 1) (CYM1ZM1(j, k) \psi_{z, j-1, k-1}' + CYZM1(j, k) \psi_{z, j, k-1}' (4.90) \\ &+ CYP1ZM1(j, k) \psi_{z, j+1, k-1}' + CYM1Z(j, k) \psi_{z, j-1, k}' + CYZ(j, k) \psi_{z, j, k}' \\ &+ CYP1Z(j, k) \psi_{z, j+1, k}' + CYM1ZP1(j, k) \psi_{z, j-1, k+1}' \\ &+ CYZP1(j, k) \psi_{z, j, k+1}' + CYP1ZP1(j, k) \psi_{z, j+1, k+1}' \\ &+ RaDa_{y} [\cos \beta (CX1(i) \theta_{i-1} + CX2(i) \theta + CX3(i) \theta_{i+1})] \\ &- \cos \alpha (CY1(j) \theta_{j-1} + CY2(j) \theta + CY3(j) \theta_{j+1})] \end{split}$$

Now we define:

$$A(I) = -\alpha_{\pm} \delta \Delta t' CX4(i)$$
 (4.91)

$$B(I) = -\alpha_{\pm} \delta \Delta t' CX5(i) + 1 \tag{4.92}$$

$$C(I) = -\alpha_{+} \delta \Delta t' CX6(i)$$
 (4.93)

$$D(I)=RHS$$
 of above equation (4.94)

simplifying the expression gives

$$A(I)\omega_{i-1}^* + B(I)\omega_{i}^* + C(I)\omega_{i+1} = D(I)$$
 (4.95)

This is a tri-diagonal equation set and can be solved as before.

The second step is to implicitly advance the iteration in the y direction:

$$\omega_{j}^{**} - \delta \alpha_{\psi} \Delta t' \frac{D a_{y}}{D a_{x}} (CY4(j) \omega_{j-1}^{**} + CY5(j) \omega_{j}^{**} + CY6(j) \omega_{j+1}^{**}) = \omega^{*}$$
 (4.96)

$$A(J) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{y}}{Da_{x}} CY4(j)$$
 (4.97)

$$B(J) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{y}}{Da_{x}} CY5(j) + 1 \qquad (4.98)$$

$$C(J) = -\alpha_{\psi} \delta \Delta t' \frac{Da_{y}}{Da_{x}} CY6(j)$$
 (4.99)

$$D(J) = \omega^* \tag{4.100}$$

Thus we have

$$A(J)\,\omega_{j-1}^{**} + B(J)\,\omega_{j}^{**} + C(J)\,\omega_{j+1}^{**} = D(J) \tag{4.101}$$

Again this is a set of tri-diagonal equations and can be solved by Thomas method.

The third step is to implicitly advance the iteration in the z direction:

$$\omega_{k}^{***} - \delta \alpha_{w} \Delta t' (CZ4(k) \omega_{k-1}^{***} + CZ5(k) \omega_{k}^{***} + CZ6(k) \omega_{k+1}^{***}) = \omega^{**}$$
 (4.102)

$$A(K) = -\alpha_{+} \delta \Delta t' CZ4(k)$$
 (4.103)

$$B(K) = -\alpha_{+}\delta \Delta t' CZ5(k) + 1 \qquad (4.104)$$

$$C(K) = -\alpha_{w} \delta \Delta t' CZ\delta(k)$$
 (4.105)

$$D(K) = \omega^{**} \tag{4.106}$$

By using the Thomas method, we obtain the final intermediate value of ω^{***} , the vector potential can be updated by using:

$$\Psi_z^{p+1} = \Psi_z^p + \alpha_{\Psi} \Delta t' \omega^{\bullet \bullet \bullet} \tag{4.107}$$

4.5.2. Solution Procedure of Temperature

The solution procedure is simple and very similar to those of vector potential.

$$\frac{\partial \theta}{\partial t'} = -R_c \vec{V}_p' \cdot \nabla' \theta + R_c \nabla'^2 \theta + \frac{R_c Q_{heat} x_0^2}{(T_h - T_c) k_{eff}}$$
(3.97)

because

$$\vec{V}_{p} \cdot \nabla' \theta = \vec{V}_{p} \cdot \nabla' \theta + \theta \nabla' \cdot \vec{V}_{p}$$

$$= \nabla' \cdot (\vec{V}_{p} \theta)$$
(4.108)

Equation (3.97) may deform to:

$$\frac{\partial \theta}{\partial t'} = -R_c \nabla' \cdot (\vec{V}_p \theta) + R_c \nabla'^2 \theta + \frac{R_c Q_{heat} x_0^2}{(T_h - T_c) k_{eff}}$$
(4.109)

We define

$$\omega = \frac{\partial \theta}{\partial t'}$$
 (4.110), and $\theta = \delta \Delta t' \omega + \theta^p$ (4.111)

we may have

$$\omega = \frac{\partial \theta}{\partial t'} = -\delta \Delta t' R_c \left[\frac{\partial (\omega u)}{\partial x} + \frac{\partial (\omega v)}{\partial y} + \frac{\partial (\omega w)}{\partial z} \right]$$

$$-R_c \left[\frac{\partial (\theta u)}{\partial x} + \frac{\partial (\theta v)}{\partial y} + \frac{\partial (\theta w)}{\partial z} \right]$$

$$+\Delta t' R_c \left[\frac{\partial^2 \omega}{\partial x^2} + \frac{\partial^2 \omega}{\partial y^2} + \frac{\partial^2 \omega}{\partial z^2} \right]$$

$$+R_c \left[\frac{\partial^2 \theta^p}{\partial x^2} + \frac{\partial^2 \theta^p}{\partial y^2} + \frac{\partial^2 \theta^p}{\partial z^2} \right]$$

$$+\frac{x_0^2 R_c Q_{heat}}{(T_h - T_c) k_{eff}}$$

$$(4.112)$$

implicit in x direction:

$$\begin{split} &\omega^* - R_c \delta \Delta t' (CX4(i)\omega_{i-1}^* + CX5(i)\omega^* + CX6(i)\omega_{i+1}^*) \\ &+ R_c \delta \Delta t' [CXI(i)(u_{i-1} \ \omega_{i-1}^*) + CX2(i)(u\omega^*) + CX3(i)(u_{i+1} \ \omega_{i+1}^*)] \\ &= R_c [CX4(i)\theta_{i-1} + CX5(i)\theta + CX6(i)\theta_{i+1}] \\ &R_c [CY4(j)\theta_{j-1} + CY5(j)\theta + CY6(j)\theta_{j+1}] \\ &+ R_c [CZ4(k)\theta_{k-1} + CZ5(k)\theta + CZ6(k)\theta_{k+1}] \\ &- R_c [CXI(i)(\theta_{i-1}v_{j-1}\theta + CY2(j)(\theta v) + CY3(j)(\theta_{j+1}v_{j+1})] \\ &- R_c [CZI(k)(\theta_{k-1}w_{k-1}) + CZ2(k)\theta w + CZ3(j)(\theta_{k+1}w_{k+1})] \\ &+ CC\theta O \end{split}$$

let

$$A(I) = Rc \delta \Delta t' CXI(i) u_{i-1} - Rc \delta \Delta t' CX4(i)$$
 (4.114)

$$B(I) = Rc \delta \Delta t' CX2(i) u_i - Rc \delta \Delta t' CX5(i) + 1$$
 (4.115)

$$C(I) = Rc \delta \Delta t' CX3(i) u_{i+1} - Rc \delta \Delta t' CX6(i)$$
 (4.116)

$$D(I) = RHS \text{ of above equation}$$
 (4.117)

By solving these equations we obtain ω^* and then forward the iteration implicitly in the y direction, we have

$$\omega^{**} - R_c \delta \Delta t' \left(CY4(j) \omega_{j-1}^{**} + CY5(j) \omega^{**} + CY6(j) \omega_{j+1}^{**} \right) + R_c \delta \Delta t' \left[CYI(j) (u_{j-1} \ \omega_{j-1}^{**}) + CY2(j) (u \omega^{**}) + CY3(j) (u_{j+1} \omega_{j+1}^{**}) \right] = \omega^{*}$$

$$(4.118)$$

$$A(J) = R_c \delta \Delta t' CYI(j) v_{i-1} - R_c \delta \Delta t' CY4(j)$$
(4.119)

$$B(J) = R_c \delta \Delta t' CY2(j) v_j - R_c \delta \Delta t' CY5(j) + 1$$
 (4.120)

$$C(J) = R_c \delta \Delta t' CY3(j) v_{i+1} - R_c \delta \Delta t' CY6(j)$$
(4.121)

$$D(J) = \omega^* \tag{4.122}$$

Similarly implicit in z,

$$\omega^{****} - R_c \delta \Delta t' (CZ4(k)\omega_{k-1}^{****} + CZ5(k)\omega^{****} + CZ6(k)\omega_{k+1}^{****}) + R_c \delta \Delta t' [CZ1(k)(w_{k-1}\omega_{k-1}^{****}) + CZ2(k)(w\omega^{****}) + CZ3(k)(w_{k+1}\omega_{k+1}^{****})]$$

$$= \omega^{***}$$
(4.123)

$$A(K) = R_c \delta \Delta t' CZI(k) w_{k-1} - R_c \delta \Delta t' CZA(k)$$
 (4.124)

$$B(K) = R_c \delta \Delta t' CZ2(k) w_k - R_c \delta \Delta t' CZ5(k) + 1$$
 (4.125)

$$C(K) = R_c \delta \Delta t' CZ3(k) w_{k+1} - R_c \delta \Delta t' CZ6(k)$$
 (4.126)

$$D(K) = \omega^{**} \tag{4.127}$$

updating θ using

$$\theta^{p+1} = \theta^p + \Delta t' \omega^{***} \tag{4.128}$$

4.6 Stability and Consistency

Next we discuss the convergency of the numerical procedure. As described by Carnahan et al (1969) the term *convergency* is understood to mean that the exact solution of the finite-difference problem (in the absence of round-off error) tends to the solution of the partial differential equation(PDE) as the grid spacings in time and distance tend to zero. There are two important concepts closely associated with the convergence of a particular finite-difference procedure, namely, those of *consistency* and *stability*.

The term *stability* denotes a property of the particular finite-difference equation(s) used as the time increment is made vanishingly small. It means that there is an upper limit (as Δt^{-1} 0) to the extent to which any piece of information, whether present in the initial conditions, or brought in via the boundary conditions, or arising from any sort of error in the calculations, can be amplified in the computations. The term *consistency*, applied to a certain finite-difference procedure, means that the procedure may in fact approximate the solution of the PDE under study, and not the solution of some other PDE. Consistency is often taken for granted.

It can be shown that, for a single linear equation, the Samarskii-Andreyev (1963) method is unconditionally stable. This scheme was stable when applied to a natural convection problem, but unfortunately it is impossible to prove or disprove the stability of it when applied to coupled, non-linear equations, Mallinson and de Vahl Davis (1973). Mallinson and de Vahl Davis (1973) also demonstrated that instability can still be introduced by the

coupling between equations of a system, but the time step Δt and false transient parameters α_{ψ} can be adjusted to control the instability and therefore a solution was still obtained. In this study we observed that if Ra>10°, a fine mesh and smaller time step was needed to make the program stable, although much more computing time was used.

4.7 Solution Procedure and Program Explanations

The arrangement of the solution procedure is discussed in this section. The numerical solutions of the governing equations were found by embedding their problem-specific discretized forms in FRECON3D, a computer program developed by Goh et al (1988). Flow charts of program AGRI_3D.FOR for this study are illustrated in Figure 4.4 and 4.5. To begin, the initial condition, boundary conditions and control variables are input by a subroutine DATIN then all the fields of vector potential, velocity, temperature and work space are initialised by subroutine INITA. Component equations of vector potential are solved by P1SOL, P2SOL and P3SOL subroutines, temperatures are advanced by TSOL and TBC, velocity fields are solved in VBC and VELOC.

ITERAT is the iteration control subroutine. It redirects the advance routine from the inner iteration to the main iteration or from the main iteration to the inner iteration. The outer iteration loop or main loop, is started from the advance routine for solving the vector potential field. Initially the ψ_z field is treated as constant in subroutines P1SOL and P2SOL, the new ψ_y is then used in subroutine P3SOL to obtain ψ_z . Every subroutine in

P1SOL, P2SOL and P3SOL includes its own third-level iteration loop to approach steady state. These processes continue until ψ_x , ψ_y and ψ_z do not change significantly, they consist of the inner iteration loops and within the inner loops, temperature is held constant.

When updated values of ψ_x , ψ_y and ψ_z are obtained, the process will jump from the inner loop and return to the main loop. Velocity field is then updated by subroutine TSOL and TBC. Once the temperature field is updated, the main iteration loop turns to the next cycle by applying the updated θ , ψ_x , ψ_y and ψ_z fields as starting points. When the maximum iteration number is reached or the solution is convergent or indicates divergence, the program will jump from the iteration loops and writes the results by calling subroutines OUTPUT and WRITER.

Program AGRI_3D.FOR is shown in Appendix D.

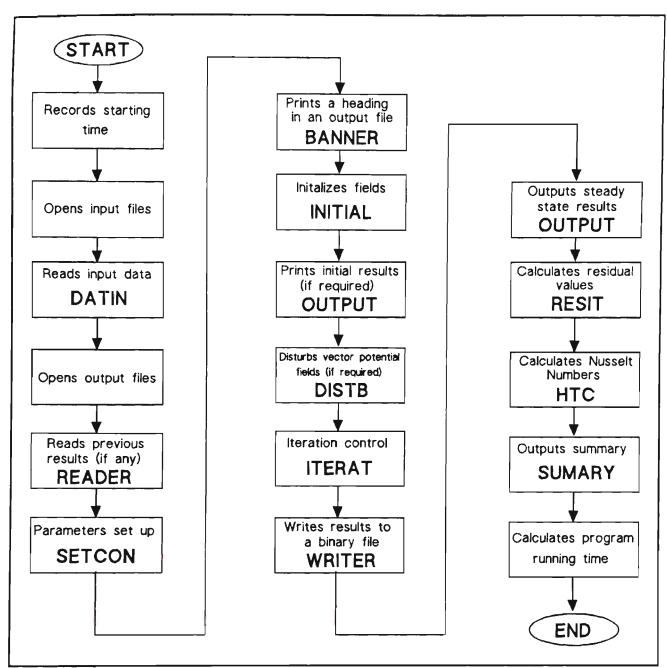


Figure 4.4 Program flow chart: main iteration loop.

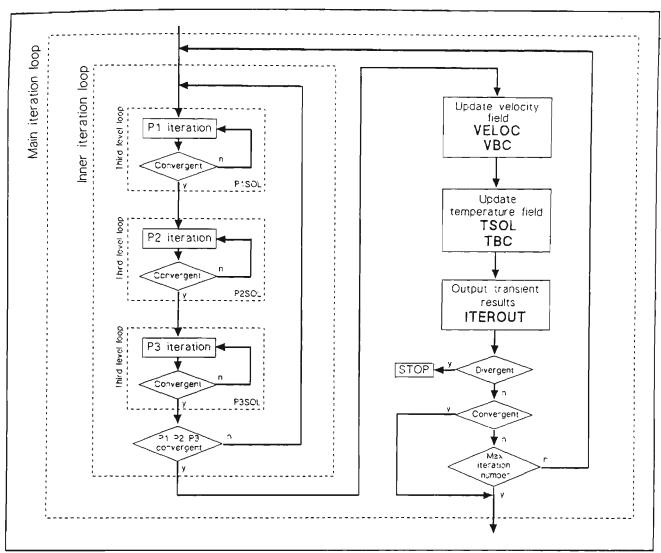


Figure 4.5 Program flow chart: inner loop.

CHAPTER 5

NUMERICAL EXPERIMENTS AND COMPARISONS WITH PRIOR WORK

5.1 Numerical Experiments

In obtaining a physically sensible solution to a set of differential equations by numerical integration, not only does correct formulation of the governing equations and the initial and boundary conditions affect the results, but, as is well known, the numerical solution procedure itself may have a significant influence on the final results. In this chapter, the effects on the solution of the mathematical model developed in this study for different time steps, grid sizes and grid patterns are investigated. As well, convergence criteria for the vector potential and temperature are examined along with the effect of varying the Rayleigh and Darcy numbers. Many numerical experiments of packaged apples in a level rectangular container had been performed to examine the effects of these factors on solutions of a range of Ra and Da numbers. Finally, the output of the program is compared with the results of Beukema's (1983) numerical study in which he characterised three-dimensional heat transfer in packed agricultural produce by assuming isotropic permeability and a constant rate of respiratory heat generation.

5.1.1 Effect of Criterion for Convergence on Steady State Potential

As described in chapter 4, before the new temperature and velocity fields are obtained,

updated vector potential should be iterated until it reaches its steady state. The criterion for convergence of the vector potentials was called PHIERR and when the condition

$$\frac{\sum_{i} \sum_{j} \sum_{k} |\psi^{p+1} - \psi^{p}|}{\sum_{i} \sum_{j} \sum_{k} |\psi^{p+1}|} \le PHIERR$$
(5.1)

was satisfied the vector potential field was iterated to a steady state. In the above inequality, superscript ^P represents the *pth* cycle of the third-level iteration loop. As shown in Table 5.1, when the product of Da and Ra is large, and the iteration time step is not small, PHIERR plays an important role in determining the final state of the vector potential.

When a uniform mesh of 11x11x11 grid is used, the differences between P2min and P3max at PHIERR = 10 and PHIERR = 0.001 were large (nearly 40%), thus PHIERR = 10 appears too large for the vector potential field to reach a steady state. Theoretically, the smaller PHIERR is, the smaller difference there is between ψ^p and ψ^{p+1} , but we can observe that ψ_2 and ψ_3 do not change significantly when PHIERR is less than 0.001. The difference between P2mins when PHIERR = 0.001 and PHIERR = 0.00001 is only 1%. So PHIERR = 0.01 is small enough to obtain reasonably accurate results for vector potential.

The iteration number in the third level iterative loop increases significantly as PHIERR decreases. When PHIERR changes from 0.001 to 0.00001, the accuracy of the vector potential field can be improved by 1%, but the third level iteration number needed is 51 times greater. This causes the program to take many more hours to run.

To balance the accuracy and economy of computation time, PHIERR should be chosen carefully. In most circumstances, PHIERR = 0.001 insures that the vector potential field converges to a satisfactory steady state while only a small number of inner iterations is needed.

A small time step for the main iteration loop can reduce the influence of PHIERR as shown in Table 5.2. It was found that when Δt was less than a critical value for a particular mesh size, there was no significant difference evident when choosing large and small values of PHIERR for the P2 and P3 iterations. Probably because the main loop time step was small, the temperature difference between one step was also small and the difference between vector potentials was also small, thus enabling the third level loop to readily reach steady state.

A further interesting result is revealed on examining Table 5.2. When the advancement time step is small, the decrease in PHIERR does not make the iteration number inside the third level loop increase rapidly. It takes 38 cycles to reach steady state when PHIERR = 10 and only 43 cycles when PHIERR = 0.001 which is 10⁴ times smaller.

| Table 5.1 | Effect of PI | Effect of PHIERR (Ra*Da=100, Ra | a=100, Ra=6. | =6.59×10 ⁶ , Da=1.518×10 ⁻⁵) | 518×10 ⁻⁵) | | |
|-----------|-------------------|---------------------------------|-----------------|---|------------------------|--------|--------------|
| Mesh Size | Time Step | PHIERR | P2min | P2max | P3min | P3max | Iter_num |
| 11 | 1. | 10. | -23.88 | 23.88 | -23.37 | -8.89 | 2 |
| 11 | 1. | 1. | -29.39 | 29.39 | -28.66 | -11.23 | ۱ ۳ |
| 11 | 1. | 0.1 | -36.03 | 36.03 | -33.65 | -14.83 | 9 |
| 11 | 1. | 0.01 | -37.95 | 37.95 | -32.23 | -17.62 | |
| 11 | | 0.001 | -38.52 | 38.52 | -27.83 | -20.03 | 51 |
| 11 | 1. | 0.0001 | -39.11 | 39.11 | -27.06 | -19.76 | 227 |
| 11 | -: | 0.00001 | -38.92 | 38.92 | -27.23 | -19.62 | 791 |
| 11 | | 0.000001 | -38.95 | 38.95 | -27.37 | -19.84 | 3115 |
| 11 | 1. | 0.0000001 | -38.94 | 38.94 | -27.34 | -19.95 | 8716 |
| 21 | 1. | 10. | -15.34 | 15.34 | -14.98 | -3.08 | 2 |
| 21 | 1. | 1. | -18.83 | 18.83 | -18.36 | -3.91 | |
| 21 | 1. | 0.1 | -24.29 | 24.29 | -22.98 | -5.79 |) [~ |
| 21 | 1. | 0.01 | -25.38 | 25.38 | -22.43 | -7.44 | 15 |
| 21 | 1. | 0.001 | -25.44 | 25.44 | -18.65 | -9.98 | 53 |
| 21 | 1. | 0.0001 | -25.75 | 25.75 | -15.60 | -10.94 | 210 |
| 21 | 1. | 0.00001 | -25.63 | 25.63 | -14.56 | -10.27 | 940 |
| 21 | 1. | 0.000001 | -25.62 | 25.62 | -14.34 | -9.69 | 3875 |
| 21 | 1. | 0.0000001 | -25.63 | 25.63 | -14.37 | -9.54 | 14425 |
| Note: | 1. x compo | x component of vector potential | potential P1=0; | ·• | | | |

2. P2 and P3 represent y and z components of vector potential; 'min' and 'max' represent the minimum and maximum values.

3. Iter_num represent the iteration number needed to reach 'steady' state within the inner loop.

Effect of PHIERR on solution of vector potential when using small time step. Table 5.2

| Mach Circ | Time Char | N. T. | | | | | |
|------------|---------------------------------------|--|---|--|---|---------------------------|----------------|
| Mesii Size | time such | PHIEKK | P2min | P2max | P3min | P3max | Iter_num |
| 5 | 0.1000 | 10.0000000 | -49,1247559 | 49 1247550 | 44 1120040 | 3072401 04 | ć |
| ¥ | 0 1000 | | 7001111111 | 77.1641.00 | 44.1170949 | 49.124/035 | 38 |
| C . | 0.1000 | 1.0000000 | -49.1247787 | 49.1247826 | -44.1121254 | 49 1247826 | 30 |
| ~ | 0.1000 | 0.1000000 | -49.1247749 | 49 1247749 | 1101054 | 36 9720010 | 3 |
| ~ | 0 1000 | 0.00000 | 10111101 | | +671711. | -30.0630019 | 1 |
|) L | 0.1000 | 0.010000 | -49.124//8/ | 49.124/711 | -44.1121292 | 49.1247711 | 41 |
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| Note: | 1. x compor 2. P2 and P3. Iter_num | x component of vector potential P1=0; P2 and P3 represent y and z components Iter_num represent the iteration number | ootential P1=0; d z components of v iteration number ne | 'ector potential; ' min ' eded to reach 'steady' | x component of vector potential P1=0; P2 and P3 represent y and z components of vector potential; 'min' and 'max' represent the minimum and maximum values. Iter_num represent the iteration number needed to reach 'steady' state within the inner loop. | e minimum and ma loop. | aximum values. |
| | | | | | | | |

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5.1.2. Effect of Iteration Time Step

Special attention must be paid to specifying iteration time steps, Δt_{main} and Δt_{inner} . In the inner loop and third level iterative loop, Δt_{inner} is specified to be large enough to reduce the running-time yet small enough to avoid instability. In the main loop, Δt_{main} is specified to be large enough to reduce the running-time yet small enough to obtain a satisfactorily accurate true transient solution. The following relations were used:

$$\Delta t_{\text{main}} = Relx \cdot h_{\text{min}}^2 \tag{5.2}$$

where Δt_{main} is the time step for the main iteration loop, Relx is the relaxation parameter to improve the solution economy and accuracy, h_{min} is the minimum grid distance. And

$$\Delta t_{inner} = \alpha_{\psi} \Delta t_{main} \tag{5.3}$$

where Δt_{inner} is the iteration time step for iterative advancement in solving the vector potential, α_w is the false transient coefficient of the vector potential.

In this study it was observed that when Ra was small, a large iteration time step could be used, but when Ra was large, a small time step improved the convergence and stability of the program. We could always find Relx and α_{ψ} to obtain a satisfied combination of Δt_{main} and Δt_{inner} for different commodities in different initial and boundary conditions. It is found that the choosing of Relx and α_{ψ} is not unique. When Δt_{main} is large, a small Δt_{inner} may be used to balance the stability. When Δt_{main} is small, a large Δt_{inner} can be used, thus improving the convergence speed in the inner loop. Figure 5.1 shows an example of choosing two sets of different Δt_{main} and Δt_{inner} to obtain the same results.

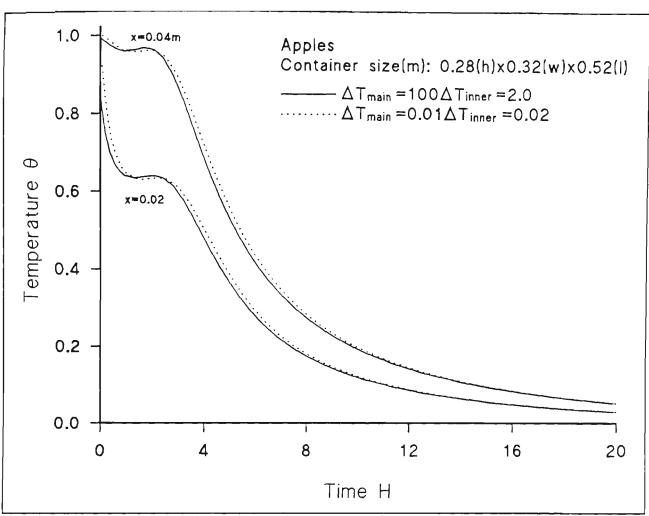


Figure 5.1 Effect of Iteration Time Step on Solution

Table 5.3 Mesh size effect on solution, Da*Ra=10

| Mesh size | Time step | PHIERR | Temperature at central | Cooling time |
|---------------------------------|---|---|--|--|
| 5 11 21 31 41 51 | 0.001 0.001 0.001 0.001 0.001 | 0.001 0.001 0.001 0.001 0.001 | 1.001165 1.003337 1.003337 1.003337 1.003337 | 1.184726834 1.184726834 1.184726834 1.184726834 1.184726834 1.184726834 |

5.1.3 Effect of Grid Size on Uniform Mesh

When using a uniform mesh, the mesh size plays a very similar role in influencing the stability to that of the time step. Also the mesh size has some influence in choosing the

iteration time steps. As we can see in equations 5.2 and 5.3, mesh size is relative to time steps.

Numerical results showed that different Ra and Da numbers required different mesh sizes to obtain the best compromise between accuracy and economy. A fine mesh caused higher time consumption but improved the convergence when *Ra* was very large. Table 5.3 shows the comparison of different mesh size effects on predicting temperature at the central point of a 0.28×0.52×0.32m container of apples, after cooling 1.184 hours at 30 °C initial temperature. It shows that a mesh size of 11×11×11 can achieve very accurate results. In this study it is found that the Samarskii-Androyev alterative direction implicit scheme has a very good stability and convergence characteristics when applied to natural convection. We can always find a satisfactory mesh size and time steps to obtain an economic and accurate solution.

5.1.4 Non-Uniform Grid Size

A non-uniform mesh can sometimes improve both the accuracy and time economy of a solution process. The design of a non-uniform mesh is usually based on a prior 'guess' or prior results of a simple uniform mesh. A non-uniform mesh was designed to perform a numerical investigation on the effect of different mesh types on the program. A narrow grid size near the walls and a wide grid size in the central regions were used to form the non-uniform mesh pattern defined below

x direction(mm): $20 \times 20 \times 28 \times 36 \times 36 \times 36 \times 36 \times 28 \times 20 \times 20$

y direction(mm): $20 \times 52 \times 52 \times 52 \times 68 \times 68 \times 68 \times 68 \times 52 \times 52 \times 20$

z direction(mm): $20 \times 20 \times 32 \times 44 \times 44 \times 44 \times 32 \times 20 \times 20$.

While it may not always be apparent how to best select a mesh pattern for a particular situation, the results shown in Table 5.4 demonstrate that a judiciously chosen non-uniform mesh can improve the accuracy of the solution and lead to some economic benefit by way of shorter CPU time. For every identical iteration step, the errors of potential and temperature are smaller using the non-uniform mesh than using the uniform mesh. To reach the same accuracy for vector potential or temperature, less iteration steps are needed, for example, to obtain a steady state (when T_error is less or equal to 1.0×10^{-5}), about 6000 main iteration steps for non-uniform mesh and 6300 main iteration steps for the uniform mesh, which is about 5% large, are needed.

Table 5.4 Effect of different types of mesh on accuracy and convergence

| | ith step | P2_error | P3_error | T_error |
|------------------|----------|----------|----------|----------|
| Non-uniform mesh | _ | | | |
| | 3000 | 0.44E-04 | 0.40E-04 | 0.30E-03 |
| | 4000 | 0.58E-04 | 0.73E-04 | 0.10E-03 |
| | 5000 | 0.18E-04 | 0.23E-04 | 0.32E-04 |
| | 6000 | 0.56E-05 | 0.70E-05 | 0.96E-05 |
| | 6400 | 0.35E-05 | 0.43E-05 | 0.59E-05 |
| uniform mesh | | | | |
| | 3000 | 0.73E-04 | 0.64E-04 | 0.40E-03 |
| | 4000 | 0.35E-04 | 0.29E-04 | 0.14E-03 |
| | 5000 | 0.32E-04 | 0.40E-04 | 0.47E-04 |
| | 6000 | 0.10E-04 | 0.12E-04 | 0.15E-04 |
| | 6400 | 0.64E-05 | 0.78E-05 | 0.91E-05 |
| | 6400 | 0.64E-05 | 0.78E-05 | 0.91E-05 |

5.2 Comparison of Results with Previous Work

Beukema (1980, 1983) conducted experimental and numerical studies on natural convection in isotropic porous media with constant heat generation rates. The results obtained by Beukema agree very well with the numerical results found in this study under the same conditions. To examine the accuracy of our program, a test was performed by using exactly the same boundary conditions and the same physical properties to obtain the temperature field and temperature versus time curves which can be compared with those of Beukema's. The data used in Beukema's study and this test are shown in Table 5.5.

Table 5.5 Data used by Beukema (1980, 1983)

| Constant rate of heat generation | 60 W/m ³ |
|---|-------------------------------------|
| Height of container | 0.5 m |
| Width of container | 0.76 m |
| Length of container | 0.76 m |
| Initial temperature | 28.75°C |
| Environment temperature | 19.2°C |
| Isotropic permeability | $1.45 \times 10^{-6} \text{ m}^2$ |
| Effective thermal conductivity | 0.25 W/mK |
| Heat capacity, air [ρ C _p] air | 1230 J/mK |
| Heat capacity, media [ρ C _p] _p | $2.3 \times 10^6 \text{ J/mK}$ |
| Dynamic viscosity, air, µ | $1.77 \times 10^{-5} \text{ kg/ms}$ |
| Porosity | 0.378 |
| Convective heat transfer coefficient at top of the container | $10 \text{ W/m}^2\text{K}$ |
| Convective heat transfer coefficient at bottom of the container | $7 \text{ W/m}^2\text{K}$ |
| Convective heat transfer coefficient at side walls of the container | $20 \text{ W/m}^2\text{K}$ |

A non-uniform grid mesh was designed to match those particular points that Beukema used to locate the temperature measurement. A 11x11x11 grid network was used with intervals of $0.11 \times 0.09 \times 0.1 \times 0.11 \times 0.09 \times 0.1 \times 0.12 \times 0.09 \times 0.09$ (m) in the x direction,

and equal intervals in the y and z directions. The criterion set for vector potential convergence was 0.001.

Figure 5.2 shows the results of Beukema's work and Figure 5.3 shows the present results. Theses figures demonstrate that the temperature versus time characteristics calculated in the two studies agree quite well.

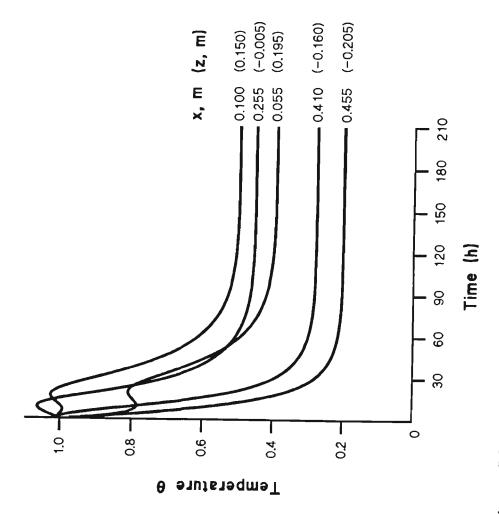


Figure 5.2 Beukema's results(1983): 'Measured and calculated (——) temperature changes with time at different locations along the central axis.

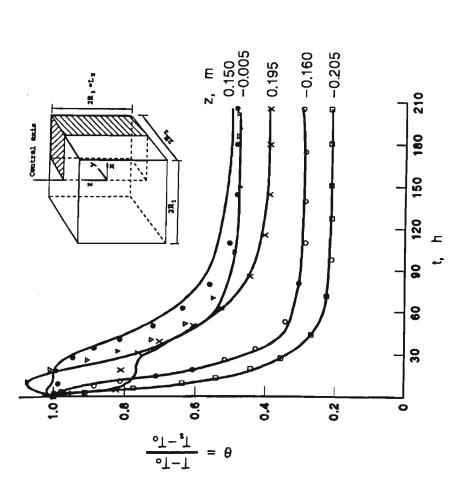


Figure 5.3 The temperature versus time curves along the central vertical axis calculated in this study. Locations correspond to those in Beukema's study.

CHAPTER 6

NUMERICAL RESULTS FOR COOLING STORED AGRICULTURAL PRODUCE

6.1 Introduction

The results of a series of numerical experiments designed to simulate the convective heat transfer processes occurring in the packed beds of selected fruits and vegetables as they are cooled are presented in this chapter. Besides modelling the characteristic variation of heat generated by respiration with temperature for each commodity, effects due to changes in the permeability of the packed bed are investigated by choosing fruits and vegetables exhibiting either isotropic or orthotropic permeability. For the comodities considered, natural convection with both adiabatic and isothermal boundary conditions imposed on the floor of the container are studied. A comprehensive discussion of the results has been reserved until the next chapter, however interpretations arising naturally from the results may be dealt with as they occur in this chapter.

Data from Table 2.2 which gives respiration rates for various commodities was used for constructing, by least squares, the respiration rate versus temperature function for apples, Brussels sprouts, carrots and asparagus in the program. The data on the physical properties of air used in the program are shown in Table 6.1.

Table 6.1 Physical data for air at atmospheric pressure, T=288K, Özisik (1985).

| Specific heat, Cp _{air} , KJ/Kg·K Air viscosity, μ, Kg/m·s | 1.0056 1.8642×10^{-5} |
|--|----------------------------------|
| | |

6.2 Produce with Isotropic Permeability

Because of their roughly spherical shapes, apples and Brussels sprouts were chosen as typical of commodities, that when packed in boxes, may be treated as packed beds with isotropic permeability. A further consideration was the desirability of studying differences between a weakly respiring commodity, characterised by apples, and a strongly respiring one, such as Brussels sprouts.

The physical properties data used in the program to investigate natural convection in a container for storing apples are given in Table 6.2.

Table 6.2 Physical data for Apples, Fikiin (1983)

| 83.5 |
|------------------------|
| 3.724 |
| 1066 |
| 657.5 |
| 0.3832 |
| 0.067 |
| 0.291×10^{-3} |
| 30° |
| 0° |
| |

Note:

1) $\varepsilon \approx 1 - \rho_0/\rho_s$;

The data on the physical properties of Brussels sprouts used in the program are shown in Table 6.3.

²⁾ Average diameter obtained from Gala Apples. It may vary from different grades or different cultivars.

Table 6.3 Physical data for Brussels Sprouts

| Water content, ϕ_{water} , %, (Hardenburg, 1986) | 84.9 |
|--|------------------------|
| Specific heat, Cp, KJ/Kg·K, (Mohsenin, 1980) | 3.684 |
| Density, ρ _s , Kg/m ^{3 1)} | 1060 |
| Average diameter, m ²⁾ | 0.029 |
| Porosity, ε^{3} | 0.3832 |
| Effective thermal conductivity in packed bed, KW/m·K ³⁾ | 0.291×10^{-3} |
| Initial temperature, °C | 30° |
| Cold wall temperature, °C | 0° |

Note:

- 1) $\rho_s = 2670/(1.67 + \phi_{water})$, Fikiin,1983;
- 2) May vary from different grades;
- 3) Assumed having the same value in Table 6.2.

6.2.1 Natural Convection with an Adiabatic Floor

The container was assumed to have an adiabatic floor, four cool isothermal side walls and a cool isothermal top. The box size was $320\text{mm}(w) \times 520\text{mm}(1) \times 280\text{mm}(h)$. The dimensions were taken from an actual package box for apples. A non-uniform grid mesh of $10 + 8 \times 32.5 + 10$ in the x direction, $10 + 10 \times 50 + 10$ in the y direction and $10 + 8 \times 37.5 + 10$ in the z direction was used. The convergence criterion was 0.001 and the main iteration time step was 0.02551.

The computed results of the evolving three-dimensional temperature and velocity fields with respiratory heat generation for apples with an adiabatic container floor are presented in Figures 6.1 to 6.12. Figure 6.1 shows the temperature response versus time at different locations along the central vertical axis of the box. At x=0.036 and x=0.152 the temperature initially decreases for some 1.5 to 3 hours, after which it plateaus and then begins to cool rapidly. While at x=0.268, x=0.384, an initial temperature rise can be observed. Some 20 hours after the cooling process first commenced a steady state temperature distribution was reached.

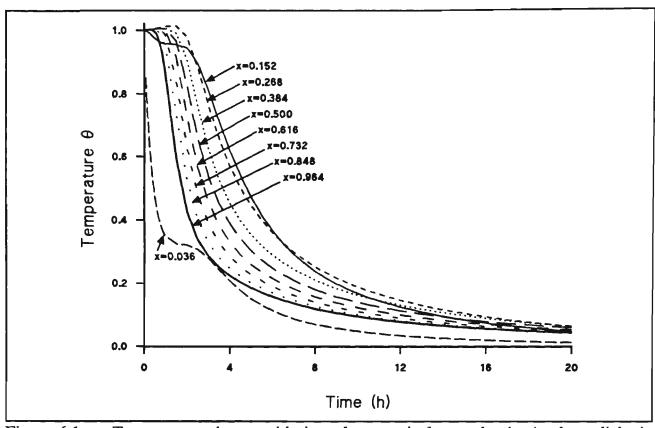


Figure 6.1 Temperature change with time along vertical central axis. Apples, adiabatic floor.

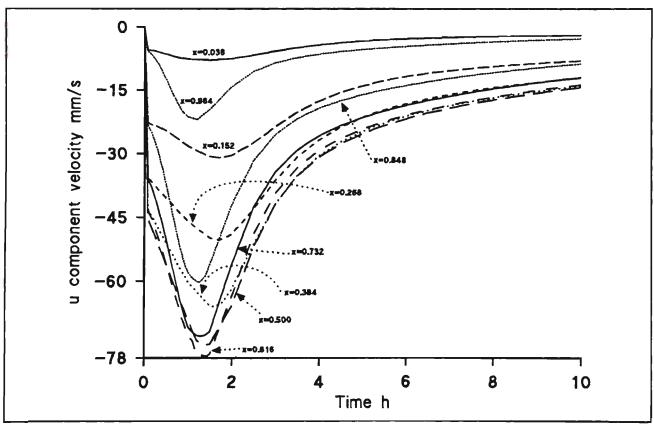


Figure 6.2 The x-component of velocity, u, versus time along the vertical central axis. Apples, adiabatic floor.

Figure 6.2 shows how the x component of velocity, u, changes along the vertical central axis with time. It apppears that strong air movement started about one hour after cooling commenced and reached its maximum after about 1.5 hours. The velocity at different positions reaches its peak value at different times. In the lower part of the container the velocity reached its maximum value before that in the upper part. The time delay between x=0.964 and x=0.152 was approximately 30 to 40 minutes.

Figures 6.1 and 6.2 indicate that high temperature gradients were associated with strong air movement inside the box. The x component velocity distribution near the top and bottom walls does not show sharp changes and the average value was relatively small compared to that in the central area.

Figures 6.3, 6.4 and 6.5 show the temperature distributions along three central axes of the box during the cooling process. Figures 6.6, 6.7 and 6.8 show the the x component velocity distributions along the three central axes. Because the system is symmetric in the $y=0.5y_0$ and $Z=0.5Z_0$ planes, the temperature and x component velocity are also symmetric along the Y and Z axes.

As shown in Figures 6.7 and 6.8, the downward air movements were limited to a narrow layer near the cold walls. Between the upward air flow and downward flow, there was a narrow zone where the velocity u was zero. It seems that the zero velocity u zone does not change position much. The absolute velocity values near the side walls were greater than those in the centre.

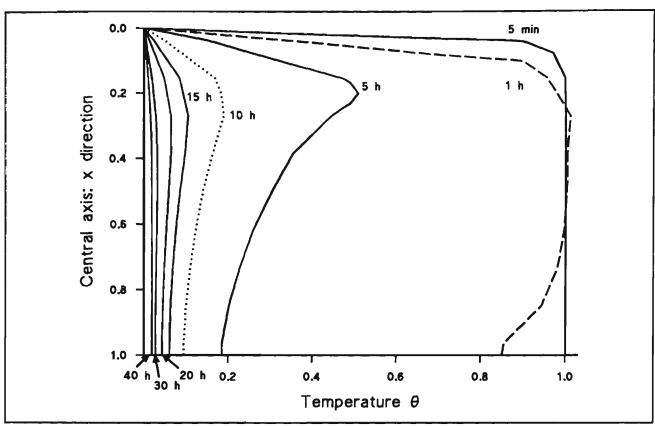


Figure 6.3 Temperature distribution at different cooling times along the central x axis. Apples, adiabatic floor.

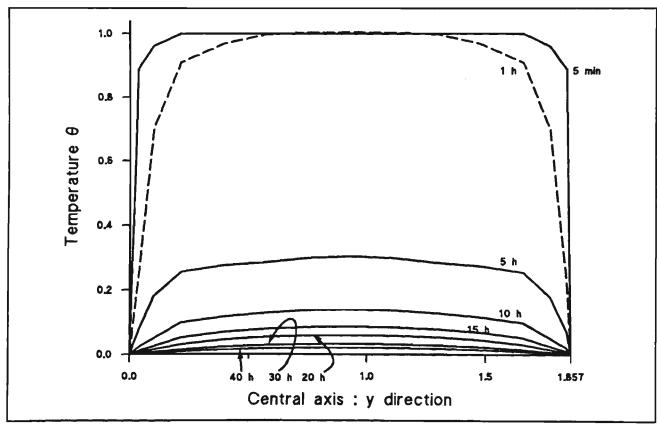


Figure 6.4 Temperature distribution at different cooling times along the central y axis. Apples, adiabatic floor.

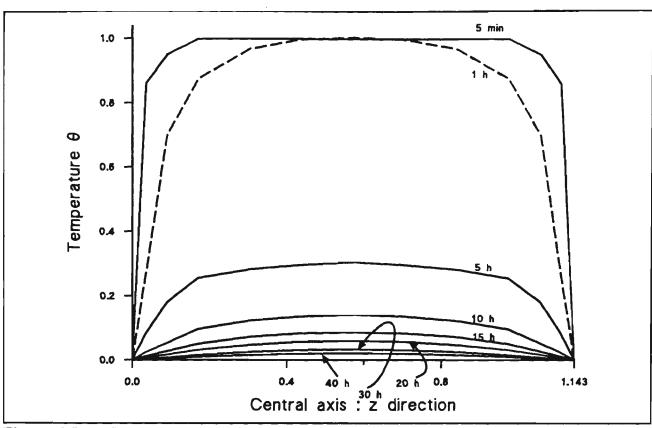


Figure 6.5 Temperature distribution at different cooling times along the central z axis. Apples, adiabatic floor.

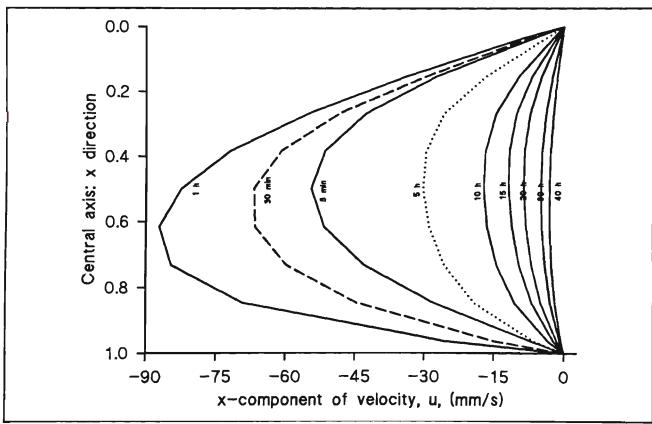


Figure 6.6 x component of velocity, u, distribution at different cooling times along the central x axis. Apples, adiabatic floor.

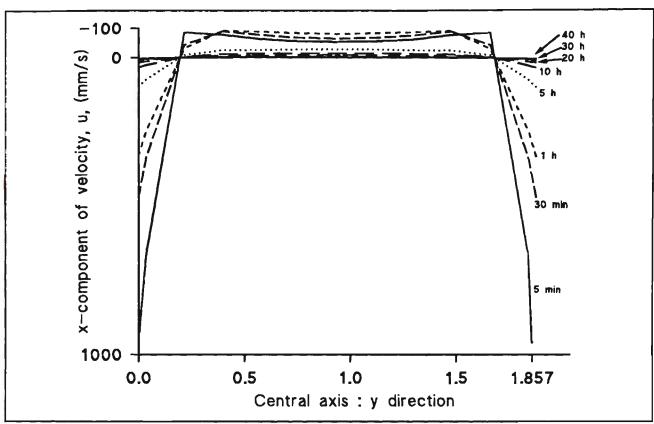


Figure 6.7 x component of velocity, u, distribution at different cooling times along the central y axis. Apples, adiabatic floor.

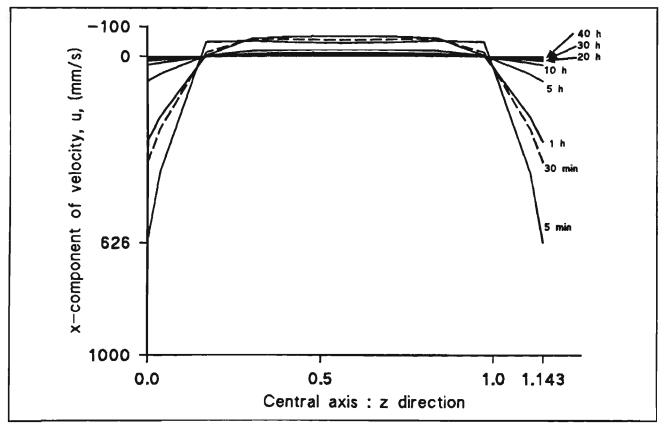


Figure 6.8 x component of velocity, u, distribution at different cooling times along the central z axis. Apples, adiabatic floor.

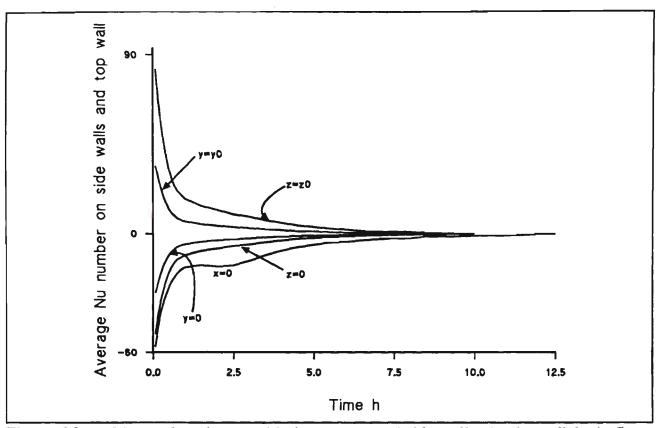


Figure 6.9 Nu number change with time on top and side walls. Apples, adiabatic floor.

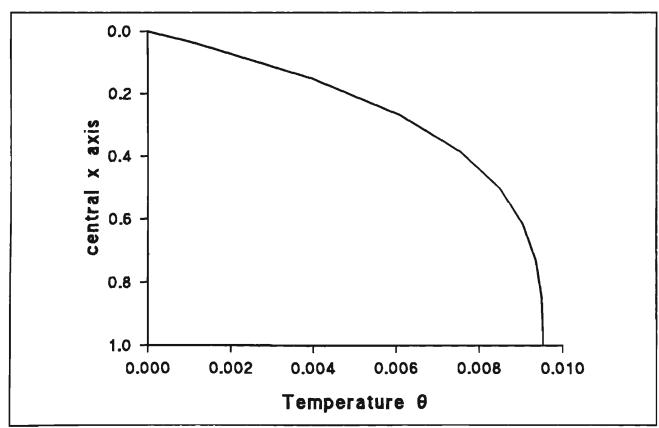


Figure 6.10 Steady state temperature distribution along the central x axis. Apples, adiabatic floor.

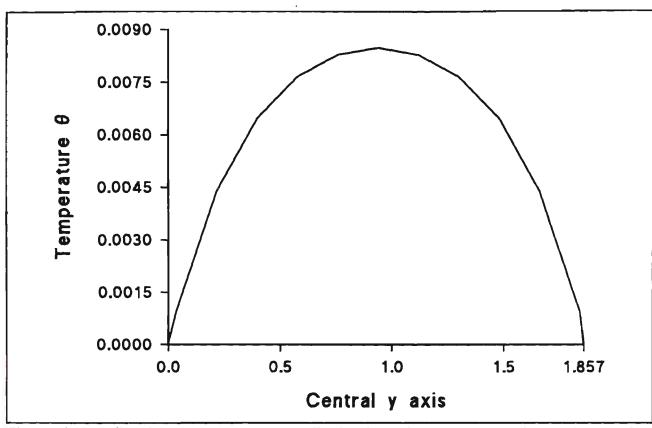


Figure 6.11 Steady state temperature distribution along the central y axis. Apples, adiabatic floor.

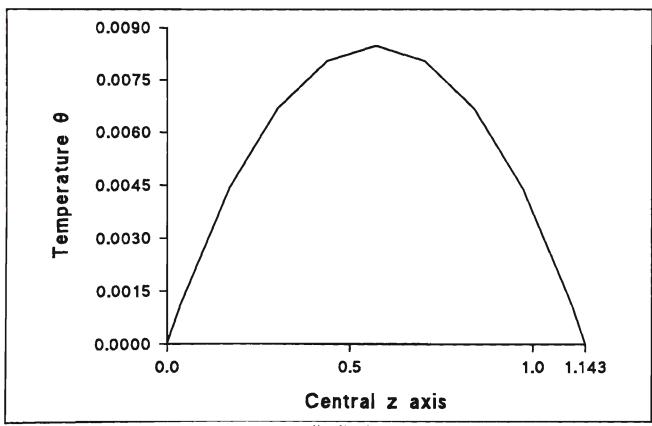


Figure 6.12 Steady state temperature distribution along the central z axis. Apples, adiabatic floor.

The average Nusselt number change with time on the side walls and the top wall is presented in Figure 6.9. In the first two hours of cooling, the Nu number had much larger values than in later stages of the process. This sugests that beyond three hours, conduction plays a more dominant role than convection in heat transfer.

Figure 6.10, 6.11, and 6.12 show the temperature distributions along the central x, y and z axes after steady state conditions were reach. The highest temperature zone was at the bottom of the box, with temperature reaching θ =0.009537 or T= 0.286°C. The temperature in the central part of the box was θ =0.008485 or T=0.255°C. At the steady state temperature, the velocity was very small and the influence of convection was weak since heat transfer was largely due to conduction. Appendix C contains the contour map of the local temperature distribution, local velocity distribution, vector potential and local Nusselt number distribution during the cooling process and at steady state.

Brussels sprouts were seleted to illustrate the ability of the program to deal with commodities characterised by high respiration rates. Brussels sprouts can be kept in good condition for a maximum period of 3 to 5 weeks at 0°C, according to Hardenbury (1986). The computed results of the developing temperature and velocity fields with respiratory heat generation for Brussels sprouts with adiabatic floor conditions are shown in Figures 6.13 to 6.24. The temperature and x-component of velocity, u, along the central vertical axis are shown in Figures 6.13 and 6.14 respectively. It is evident that a much greater time was needed to cool the sprouts than was the case for apples. The temperature distributions within the container along the central axes for the x,y and z coordinates, as it develops in time, are shown in Figure 6.15, 6.16 and 6.17.

The development of the velocity fields with time are illustrated in Figures 6.18, 6.19 and 6.20, where the x component of velocity distributions for the x,y and z coordinates along the central axes are shown. Figures 6.21, 6.22 and 6.23 depict the steady state temperature distributions along the central x,y and z coordinates respectively. The average Nusselt number change with time on the side walls and the top wall is presented in Figure 6.24.

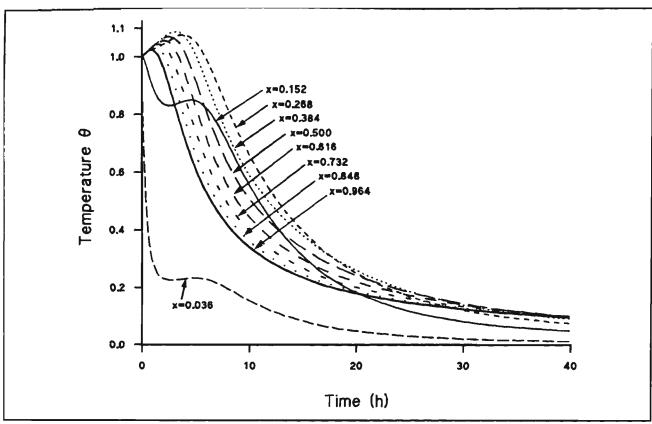


Figure 6.13 Temperature change with time along the vertical central x axis. Brussels sprouts, adiabatic floor.

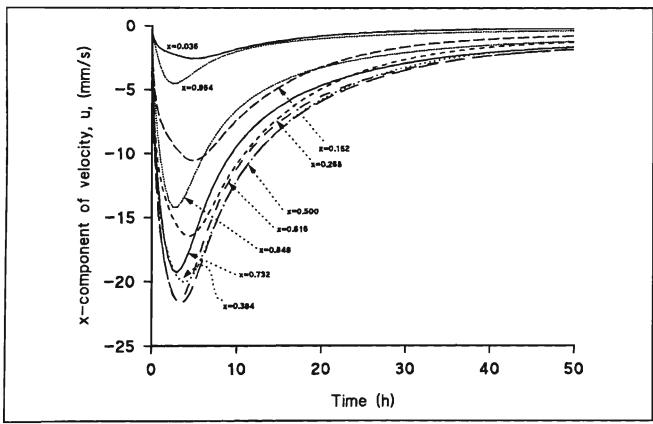


Figure 6.14 x-component of velocity, u, change with time along the vertical x central axis. Brussels sprouts, adiabatic floor.

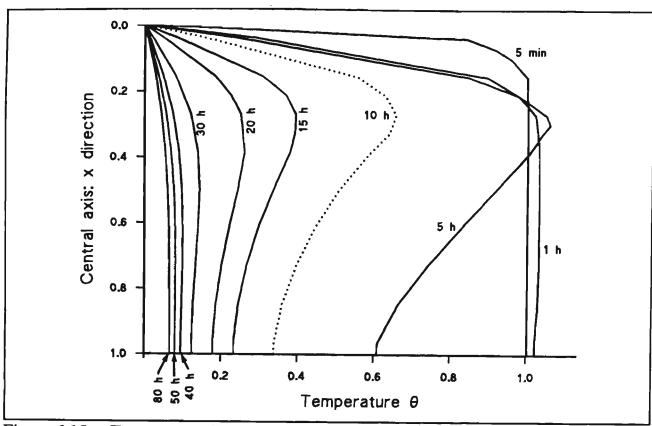


Figure 6.15 Temperature distribution at different cooling times along the central x axis. Brussels sprouts, adiabatic floor.

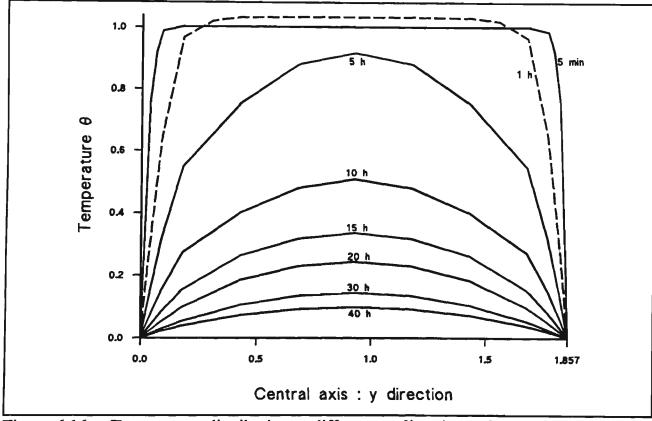


Figure 6.16 Temperature distribution at different cooling times along the central y axis. Brussels sprouts, adiabatic floor.

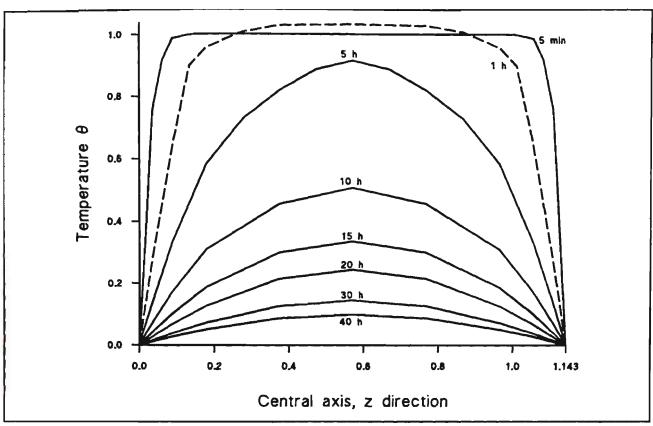


Figure 6.17 Temperature distribution at different cooling times along the central y axis.

Brussels sprouts, adiabatic floor.

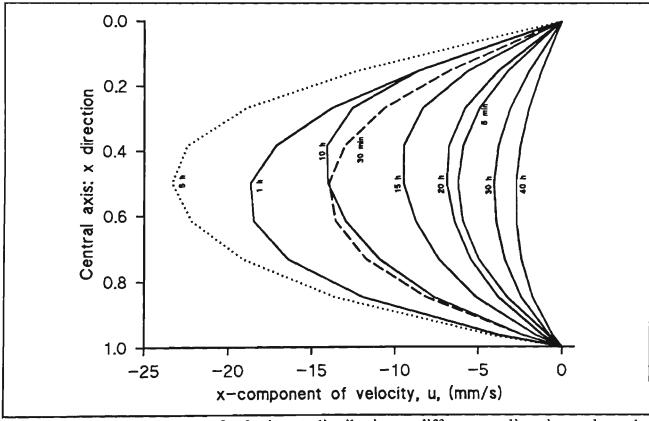


Figure 6.18 x-component of velocity, u, distribution at different cooling times along the central x axis. Brussels sprouts, adiabatic floor.

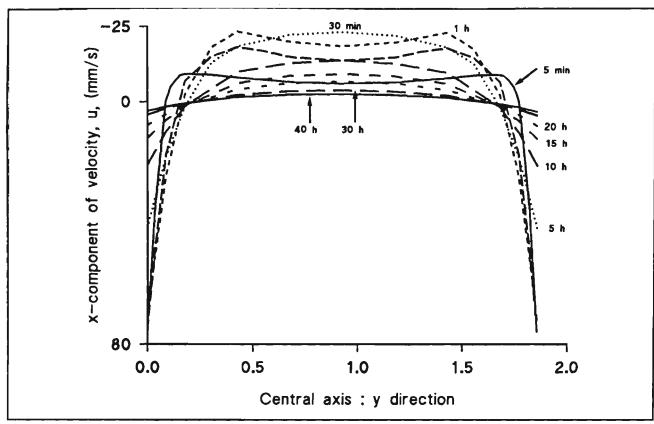


Figure 6.19 x-component of velocity, u, distribution at different cooling times along the central y axis. Brussels sprouts, adiabatic floor.

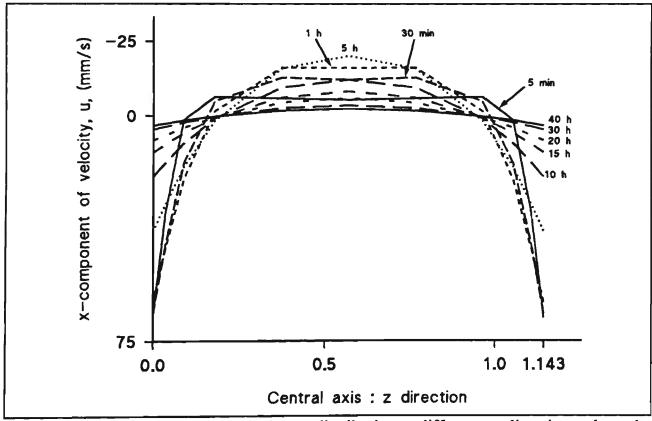


Figure 6.20 x-component of velocity, u, distribution at different cooling times along the central z axis. Brussels sprouts, adiabatic floor.

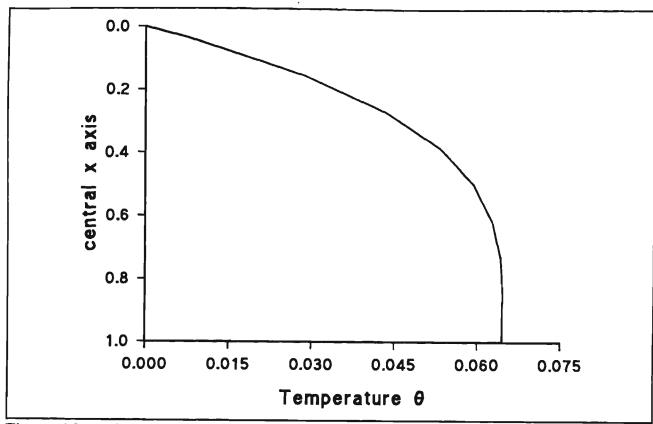


Figure 6.21 Steady state temperature distribution along the central vertical x axis. Brussels sprouts, adiabatic floor.

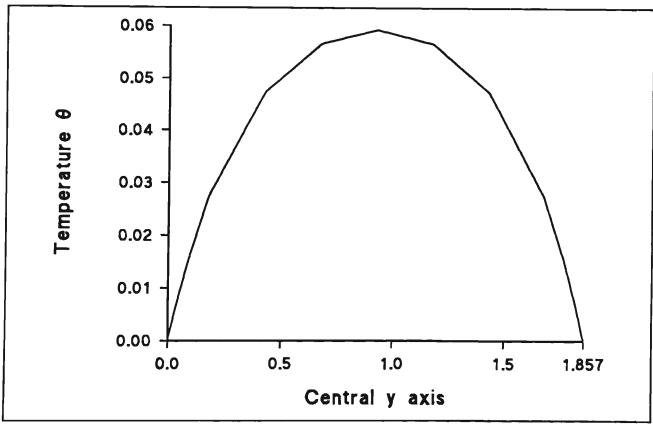


Figure 6.22 Steady state temperature distribution along the central horizontal y axis. Brussels sprouts, adiabatic floor.

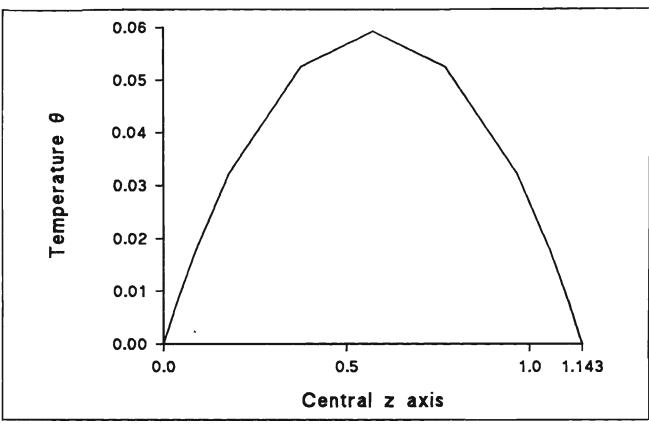


Figure 6.23 Steady state temperature distribution along the central z axis. Brussels sprouts, adiabatic floor.

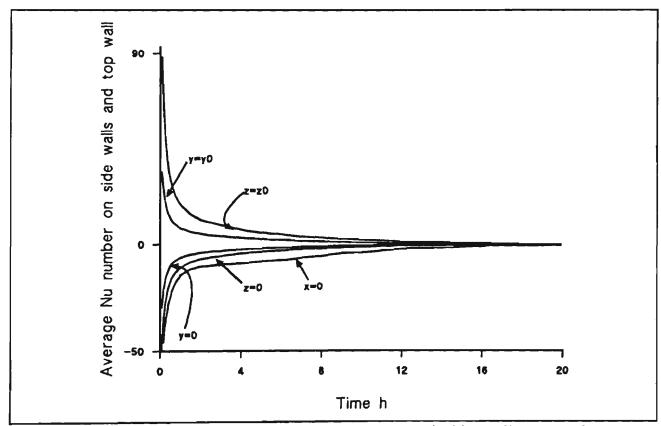


Figure 6.24 Nu number change with time on top and side walls. Brussels sprouts, adiabatic floor.

6.2.2 Natural Convection with an Isothermal Floor

The results computed for apples cooled under isothermal boundary conditions imposed on the floor of the storage container are presented below in Figures 6.25 to 6.36.

Progressive changes in the temperature destribution with time along the central x axis for apples is shown in Figure 6.25. After some 40 hours the temperature within the packed box reached steady state. Changes in the x-component of velocity, u, distribution with time along the central vertical axis are shown in Figure 6.26. Figures 6.27, 6.28 and 6.29 show the temperature distributions within the container along the central axes for the x,y and z coordinates, as it develops in time. Figures 6.30, 6.31 and 6.32 show the development of the x component of velocity with time along the central axes. The steady state temperature distributions along the central x,y and z directions are shown in Figures 6.33, 6.34 and 6.35 respectively. The average Nusselt number change with time on the side walls and the top wall is presented in Figure 6.36.

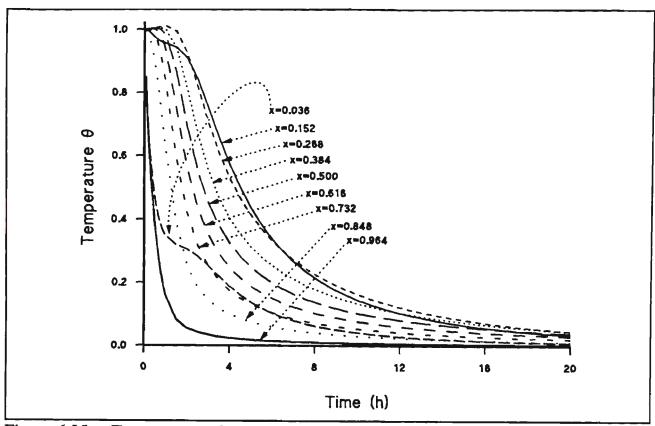


Figure 6.25 Temperature change with time along the vertical central axis. Apples, isothermal floor.

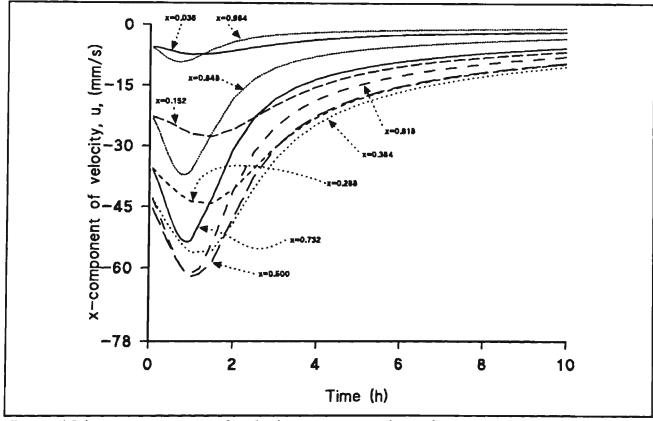


Figure 6.26 x-component of velocity, u, versus time along the vertical central axis. Apple, isothermal floor.

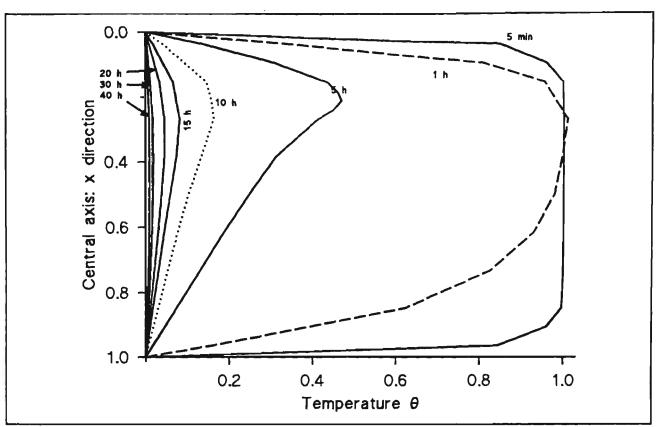


Figure 6.27 Temperature distribution at different cooling times along the central x axis. Apples, isothermal floor.

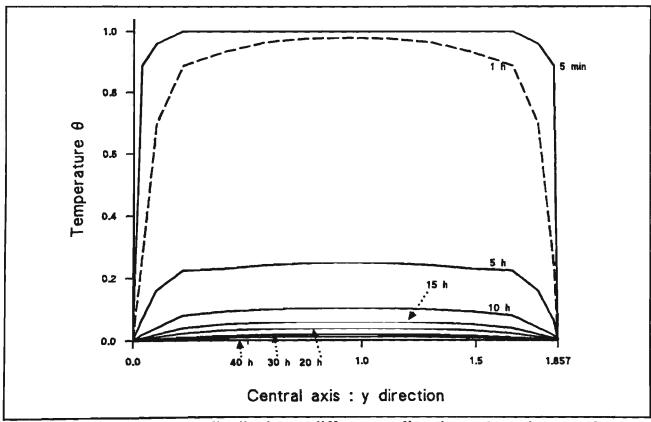


Figure 6.28 Temperature distribution at different cooling times along the central y axis. Apples, isothermal floor.

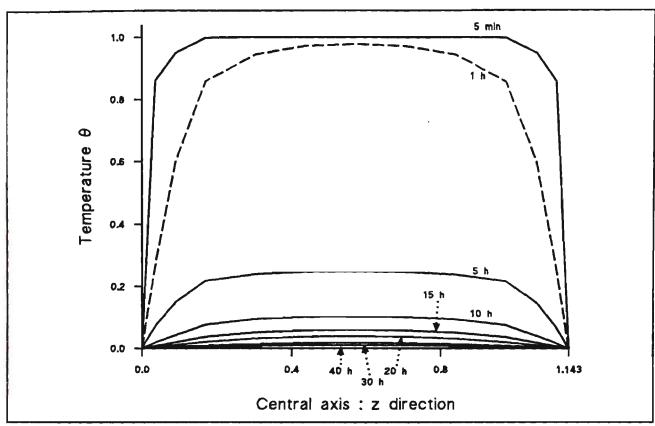


Figure 6.29 Temperature distribution at different cooling times along the central x axis. Apples, isothermal floor.

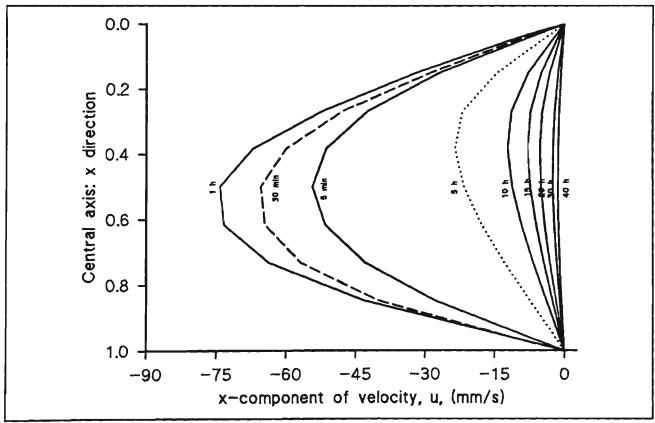


Figure 6.30 x-component of velocity, u, distribution at different cooling times along the central x axis. Apples, isothermal floor.

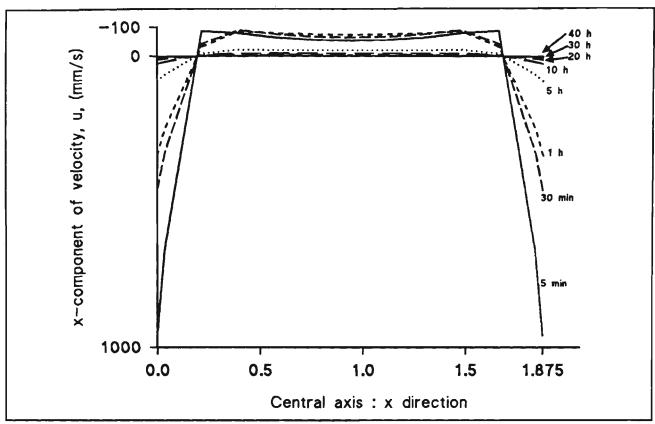


Figure 6.31 x-component of velocity, u, distribution at different cooling times along central y axis. Apples, isothermal floor.

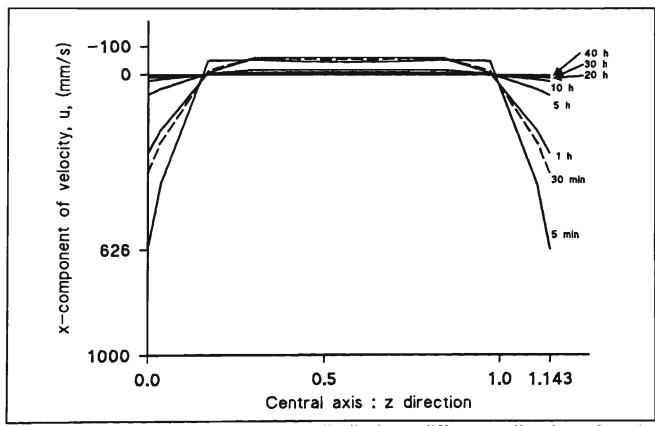


Figure 6.32 x-component of velocity, u, distribution at different cooling times along the central z axis. Apples, isothermal floor.

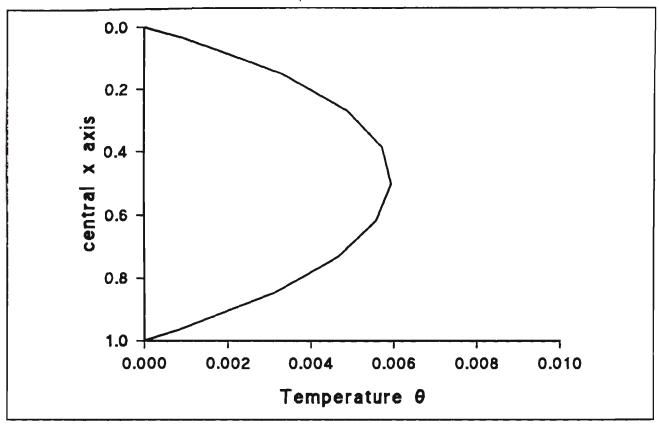


Figure 6.33 Steady state temperature distribution along the central x axis. Apples, isothermal floor.

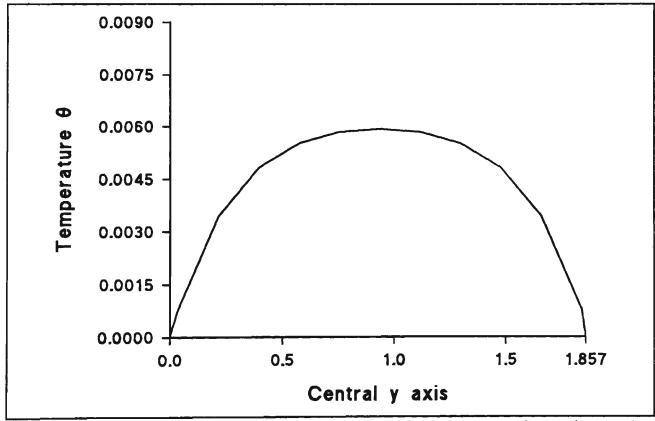


Figure 6.34 Steady state temperature distribution along the central y axis. Apples, isothermal floor.

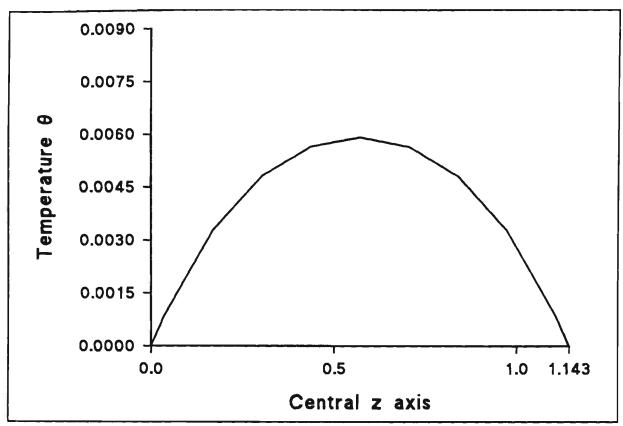


Figure 6.35 Steady state temperature distribution along the central z axis. Apples, isothermal floor.

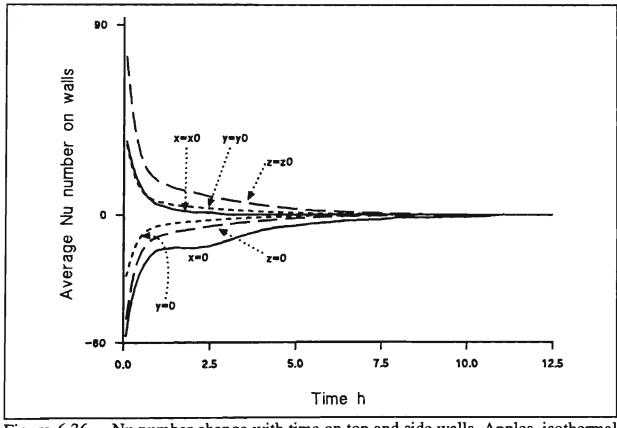


Figure 6.36 Nu number change with time on top and side walls. Apples, isothermal floor.

The results computed for Brussels sprouts cooled under isothermal boundary conditions imposed on the floor of the storage container are presented below in Figures 6.37 to 6.48.

Progressive changes in the temperature destribution with time along the central x axis for Brussels sprouts is shown in Figure 6.37. After some 40 hours the temperature within the packed box reached steady state. Changes in the x-component of velocity, u, distribution with time along the central vertical axis are shown in Figure 6.38. Figures 6.39, 6.40 and 6.41 show the temperature distributions within the container along the central axes for the x,y and z coordinates, as it develops in time. Figures 6.42, 6.43 and 6.44 show the development of the x component of velocity with time along the central axes. The steady state temperature distributions along the central x,y and z directions are shown in Figures 6.45, 6.46 and 6.47 respectively. The average Nusselt number change with time on the side walls and the top wall is presented in Figure 6.48.

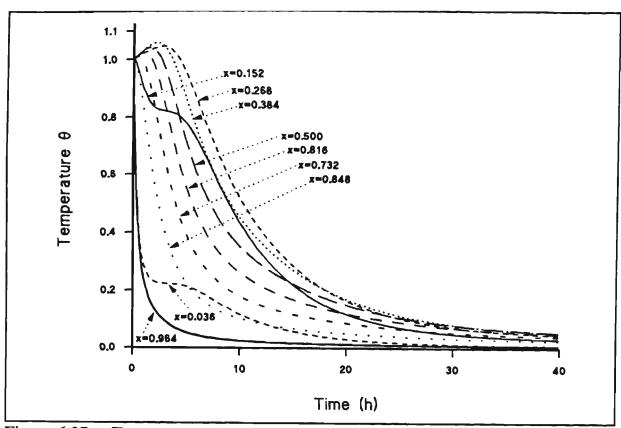


Figure 6.37 Temperature change with time along the vertical central x axis. Brussels sprouts, isothermal floor.

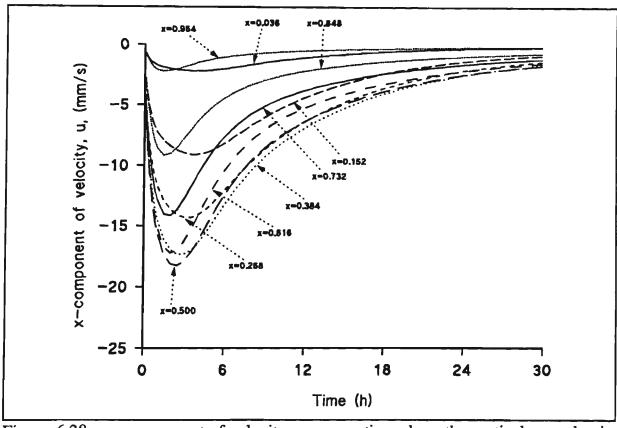


Figure 6.38 x-component of velocity, u, versus time along the vertical central axis.

Brussels sprouts, isothermal floor.

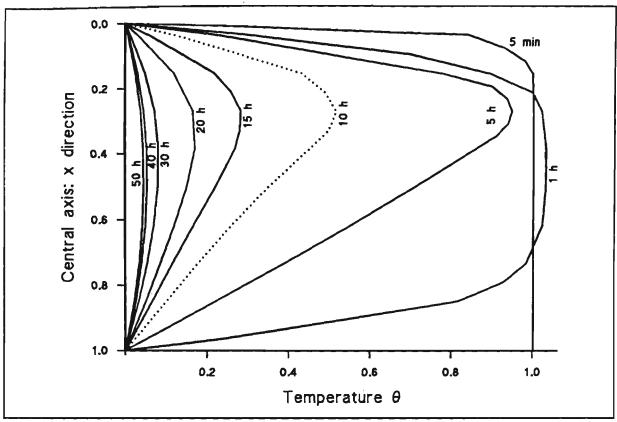


Figure 6.39 Temperature distribution at different cooling times along the central x axis. Brussels sprouts, isothermal floor.

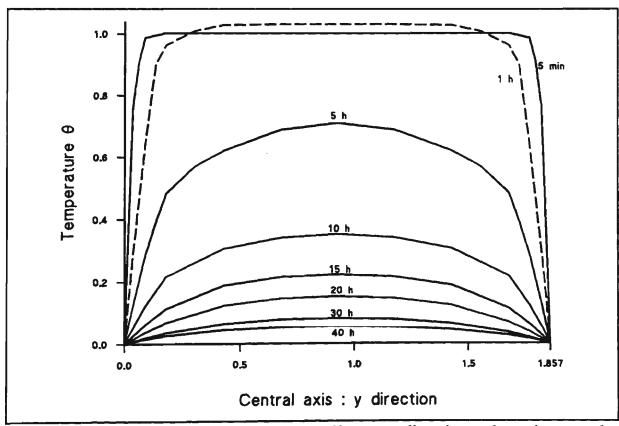


Figure 6.40 Temperature distribution at different cooling times along the central y axis. Brussels sprouts, isothermal floor.

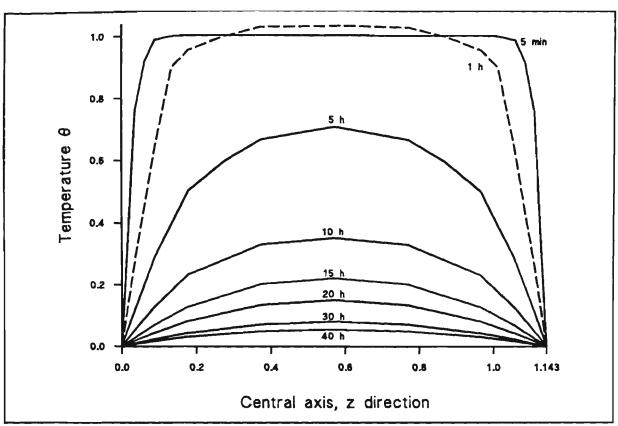


Figure 6.41 Temperature distribution at different cooling times along the central y axis, Brussels sprouts, isothermal floor.

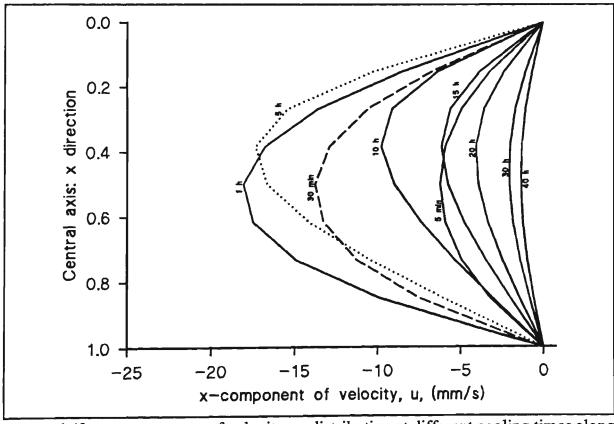


Figure 6.42 x-component of velocity, u, distribution at different cooling times along the central x axis. Brussels sprouts, isothermal floor.

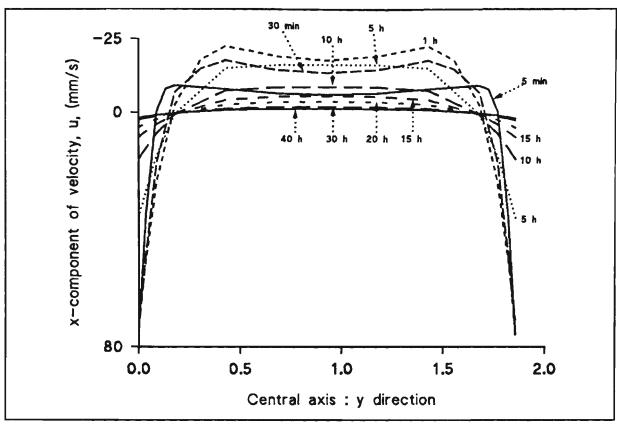


Figure 6.43 x-component of velocity, u, distribution at different cooling times along the central y axis. Brussels sprouts, isothermal floor.

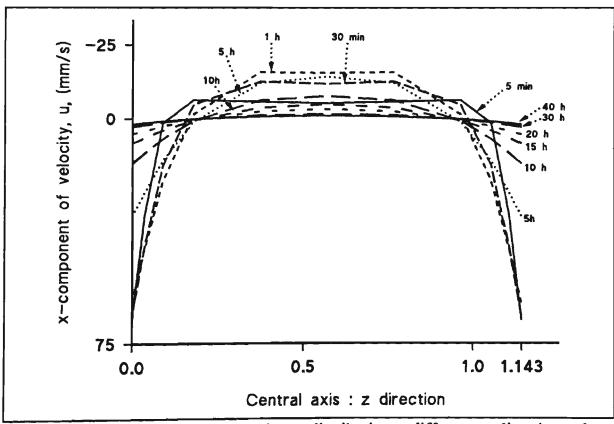


Figure 6.44 x-component of velocity, u, distribution at different cooling times along the central z axis. Brussels sprouts, isothermal floor.

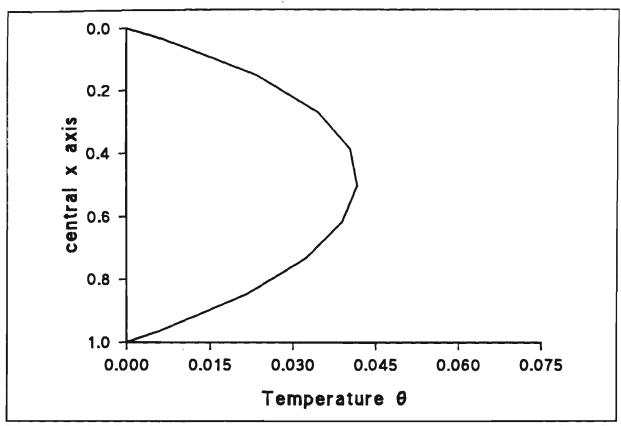


Figure 6.45 Steady state temperature distribution along the central vertical x axis. Brussels sprouts, isothermal floor.

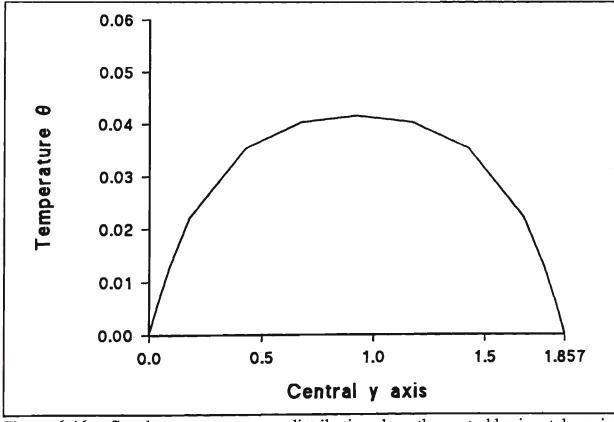


Figure 6.46 Steady state temperature distribution along the central horizontal y axis, Brussels sprout. isothermal floor.

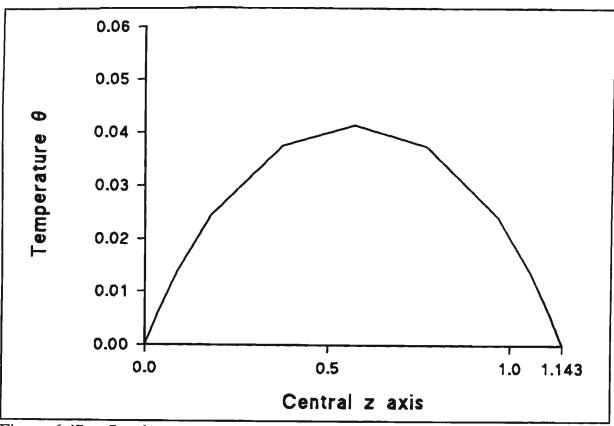


Figure 6.47 Steady state temperature distribution along the central z axis. Brussels sprouts, isothermal floor.

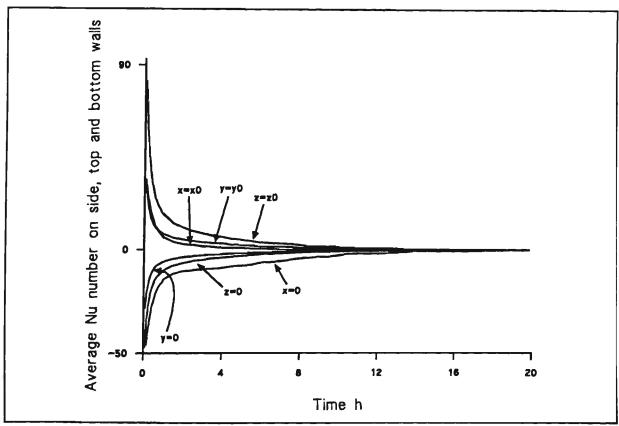


Figure 6.48 Nu number change versus time on top and side walls. Brussels sprouts, isothermal floor.

6.3 Produce with Orthotropic Permeability

Carrots and asparagus packed in boxes $0.28m \times 0.52m \times 0.32m$ were chosen as representative of the orthotropic permeability characteristics of packed produce undergoing convective heat transfer. Data describing the physical properties of carrot, which has a low respiration rate, and asparagus, which has a high respiration rate are shown in Tables 6.4 and 6.5 repectively.

Table 6.4 Physical properties of Carrots

| Water content, ϕ_{water} , %, (Hardenburg, 1986) | 88.2 |
|---|------------------------|
| Specific heat, Cp, KJ/Kg·K, (Mohsenin, 1980) | 3.768 |
| Density, ρ_s , Kg/m ^{3 1)} | 1046 |
| Density of packed bed, ρ _p , Kg/m ³ , (Mohsenin,1986) Average effective diameter, m ²) | 641 |
| Average effective diameter, m ²⁾ | 0.041 |
| Porosity, ε^{3} | 0.3872 |
| Effective thermal conductivity in packed bed, KW/m·K ⁴⁾ | 0.291×10^{-3} |
| Initial temperature, °C | 30° |
| Cold wall temperature, °C | 0° |
| | |

Note:

- 1) $\rho_n = 2670/(1.67 + \phi_{water})$, Fikiin,1983;
- 2) May vary from different grades. See Equation 3.23;
- 3) $\varepsilon \approx 1 \rho_0 / \rho_s$;
- 4) Assumed having the same value in Table 6.2.

Table 6.5 Physical properties of Asparagus

| Water content, ϕ_{water} , %, (Hardenburg, 1986) | 93.0 |
|--|------------------------|
| Specific heat, Cp _s , KJ/Kg·K, (Mohsenin, 1980) | 3.936 |
| Density, ρ_s , Kg/m ^{3 1)} | 1027 |
| Density of packed bed, ρ_p , Kg/m ³ , (Mohsenin, 1986) | 577 |
| Average effective diameter, m ²⁾ | 0.02 |
| Porosity, ε^{3} | 0.4382 |
| Effective thermal conductivity in packed bed, KW/m·K ⁴⁾ | 0.291×10^{-3} |
| Initial temperature, °C | 30° |
| Cold wall temperature, °C | 0° |

Note:

- 1) $\rho_a = 2670/(1.67 + \phi_{water})$, Fikiin, 1983;
- 2) May vary from different grades. See Equation 3.23;
- 3) $\varepsilon \approx 1 \rho_0 / \rho_s$;
- 4) Assumed having the same value in Table 6.2.

As previously, Table 2.2 was used to determine the respiration rate versus temperature functions for carrots and asparagus. The numerical experiments described in this section were

performed on boxes experencing adiabatic floor conditions and isothermal cooling on the sides and top.

6.3.1 Horizontally Laid Pack

When produce such as asparagus, cucumber, celery, beans or carrots are laid horizontally in boxes, one of the horizontally directed permeabilities, say K_y, has a value different to the other two, K_x, K_z. In order to examine the effect of horizontal packing on heat transfer, four different relationships between the components of permeability were used in computing the results for carrots. The relationships used were: $Da_y = Da_z = Da_z$; $Da_y = 2Da_z = 2Da_z$; $Da_y = 3Da_z = 3Da_z$; $Da_y = 4Da_z = 4Da_z$.

The temperature versus time curves computed for the four different permeabilities for horizontally packed carrots are shown in Figure 6.49 and the temperature distribution along the central axes in the x, y, and z directions are shown in Figures 6.50, 6.51 and 6.52 respectively. Velocity profiles have been computed after cooling for one hour and after five hours, shown in Figures 6.53, 6.54 and 6.55.

Temperature distributions along the x, y and z diresctions were computed at steady state conditions and the results are shown in Figures 6.56, 6.57 and 6.58 for carrots.

A paralllel set of results using the same boundary conditions and permeability relationships were computed for horizontally laid asparagus. These results are presented in Figures 6.59 through to 6.68.

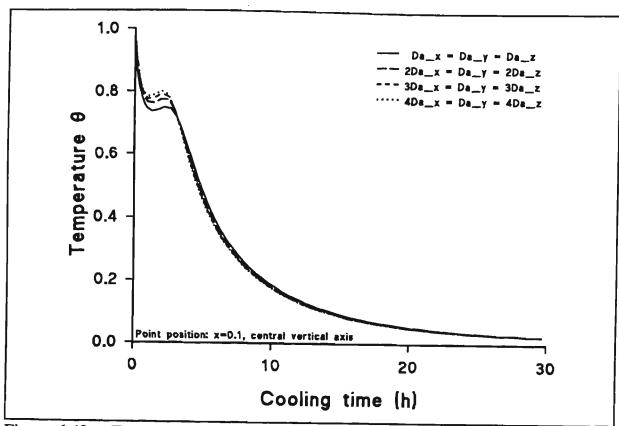


Figure 6.49 Temperature versus time curves for horizontally laid carrots, adiabatic floor.

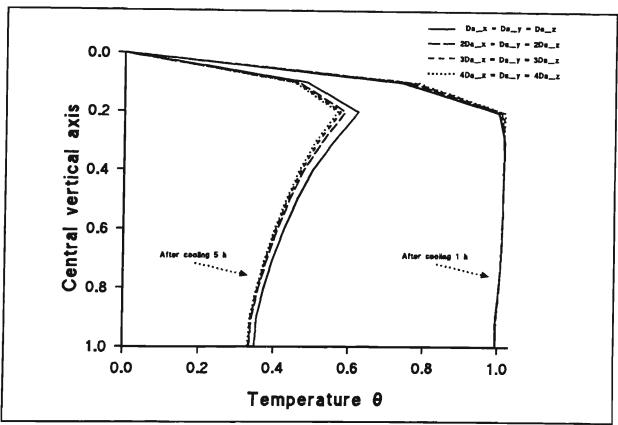


Figure 6.50 Temperature distributions along the central vertical axis for horizontally laid carrots, adiabatic floor.

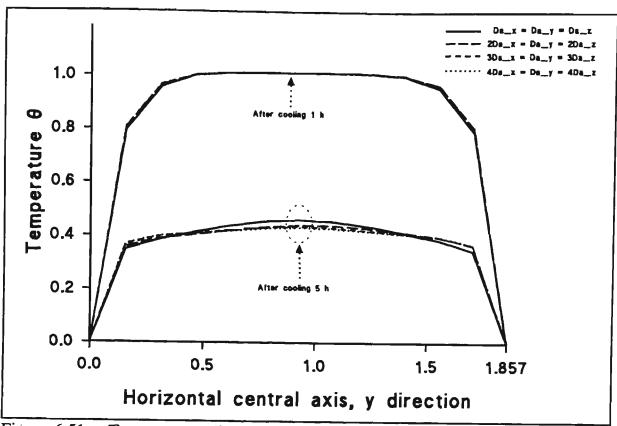


Figure 6.51 Temperature distributions along the central horizontal y axis for horizontally laid carrots, adiabatic floor.

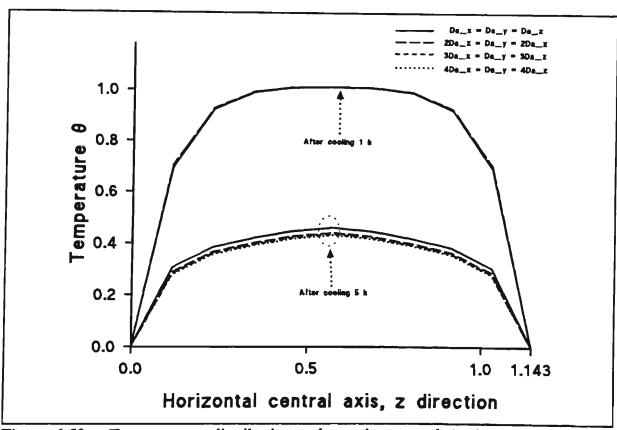


Figure 6.52 Temperature distributions along the central horizontal z axis for horizontally laid carrots, adiabatic floor.

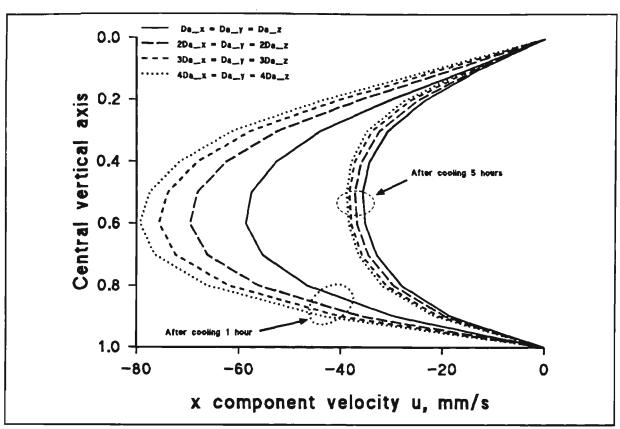


Figure 6.53 x-component of velocity, u, distributions along the central vertical x axis for horizontally laid carrots, adiabatic floor.

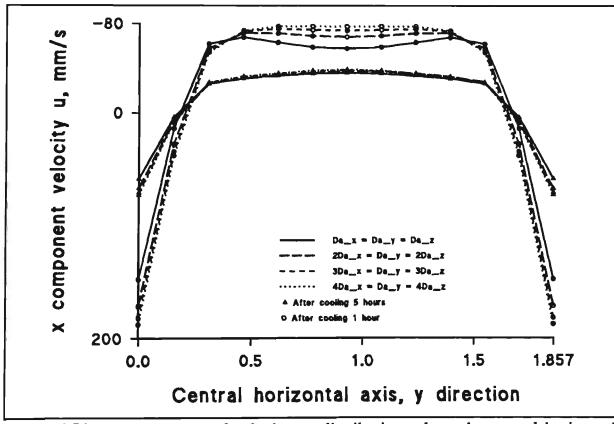


Figure 6.54 x-component of velocity, u, distributions along the central horizontal y axis for horizontally laid carrots, adiabatic floor.

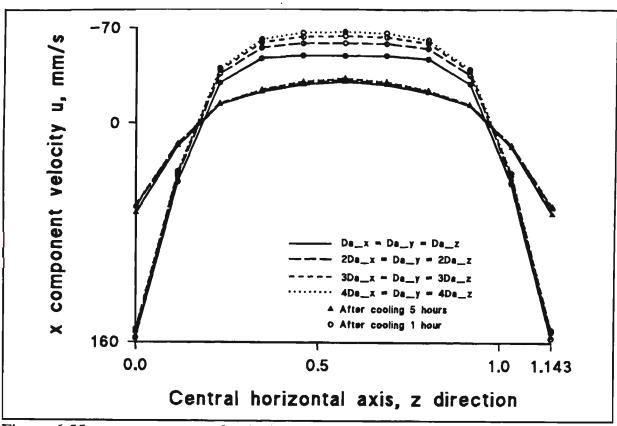


Figure 6.55 x-component of velocity, u, distributions along the central horizontal z axis for horizontally laid carrots, adiabatic floor.

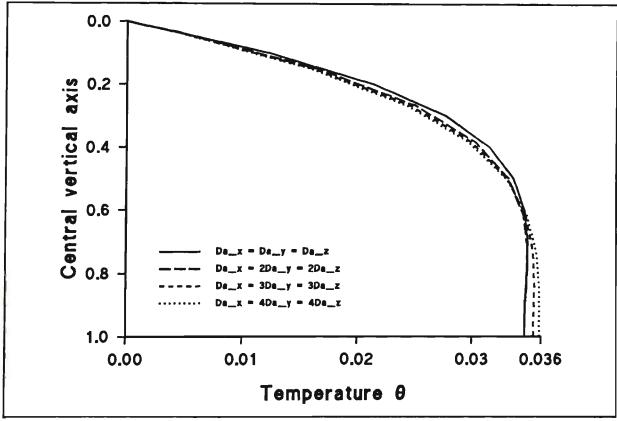


Figure 6.56 Temperature distributions along the central vertical x axis at steady state for horizontally laid carrots, adiabatic floor.

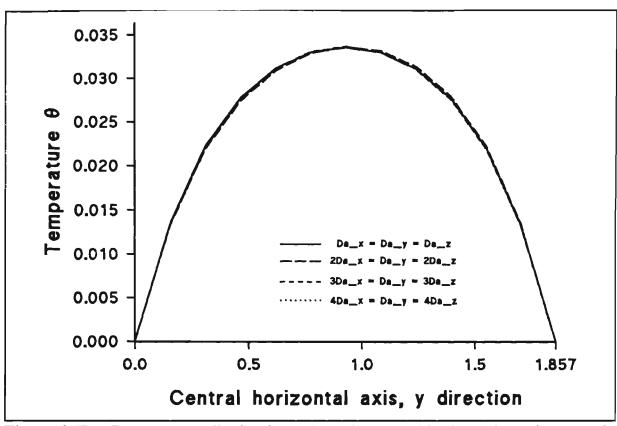


Figure 6.57 Temperature distributions along the central horizontal y axis at steady state for horizontally laid carrots, adiabatic floor.

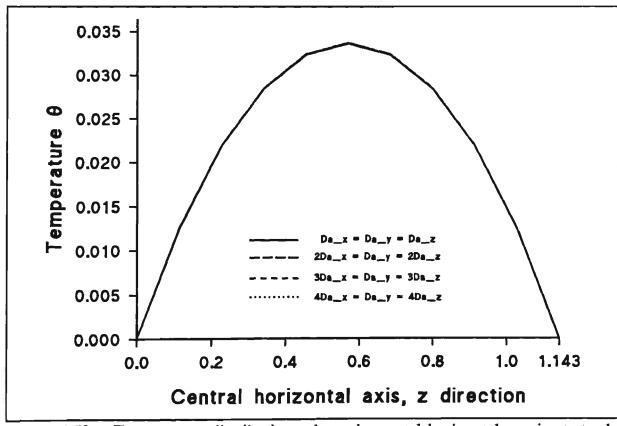


Figure 6.58 Temperature distributions along the cental horizontal z axis at steady state for horizontally laid carrots, adiabatic floor.

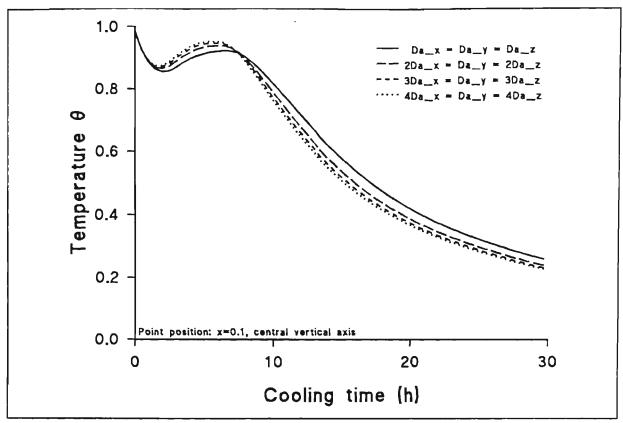


Figure 6.59 Temperature versus time curves for horizontally laid asparagus, adiabatic floor.

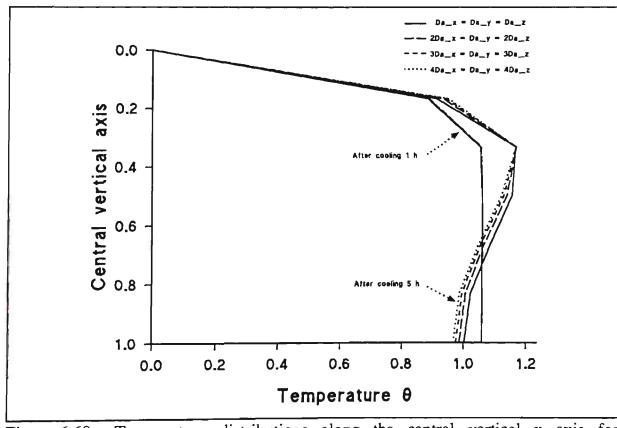


Figure 6.60 Temperature distributions along the central vertical x axis for horizontally laid asparagus, adiabatic floor

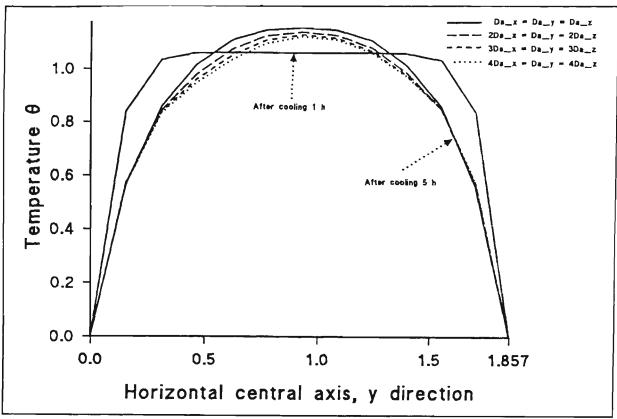


Figure 6.61 Temperature distributions along the central horizontal y axis for horizontally laid asparagus, adiabatic floor.

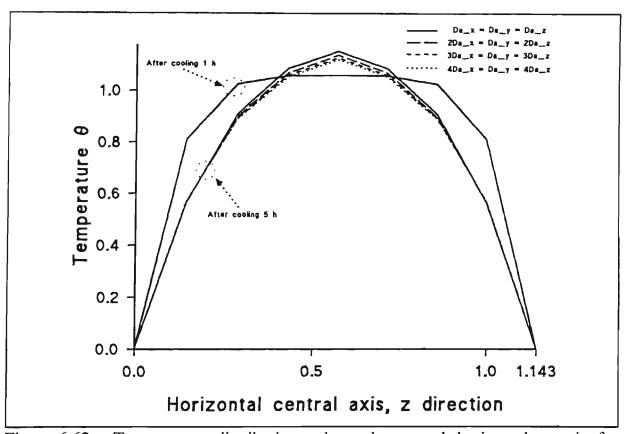


Figure 6.62 Temperature distributions along the central horizontal z axis for horizontally laid asparagus, adiabatic floor.

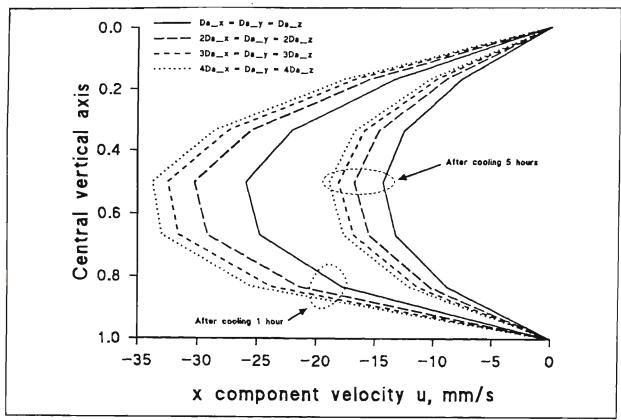


Figure 6.63 x-component of velocity, u, distributions along the central vertical x axis for horizontally laid asparagus, adiabatic floor.

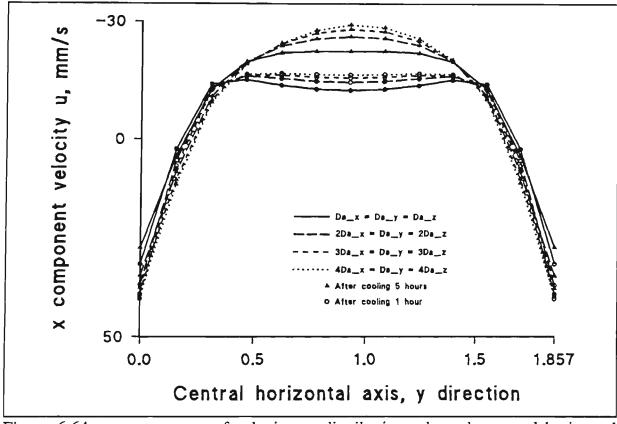


Figure 6.64 x-component of velocity, u, distributions along the central horizontal y axis for horizontally laid asparagus, adiabatic floor.

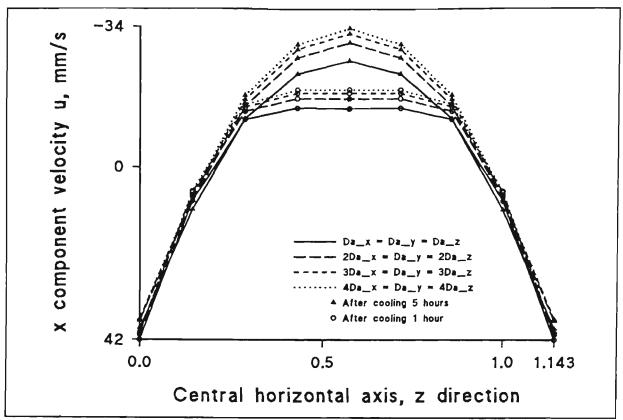


Figure 6.65 x-component of velocity, u, distributions along the central horizontal z axis for horizontally laid asparagus, adiabatic floor.

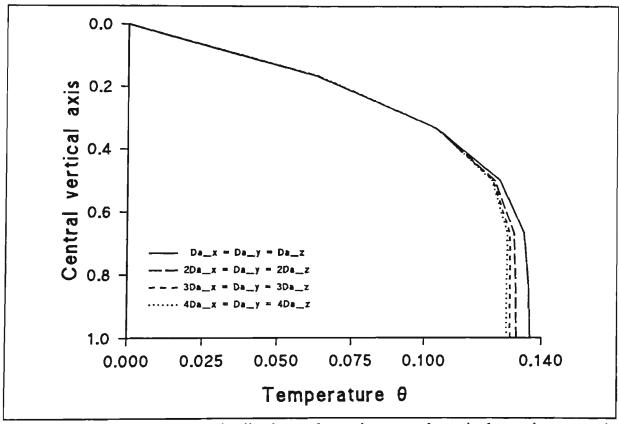


Figure 6.66 Temperature distributions along the central vertical x axis at steady state for horizontally laid asparagus, adiabatic floor.

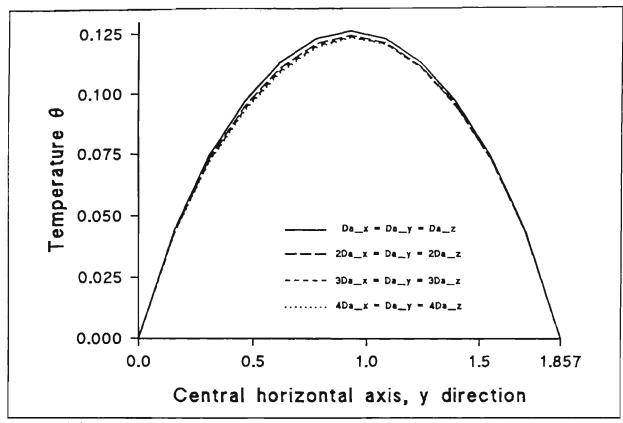


Figure 6.67 Temperature distributions along the central horizontal y axis at steady state for horizontally laid asparagus, adiabatic floor.

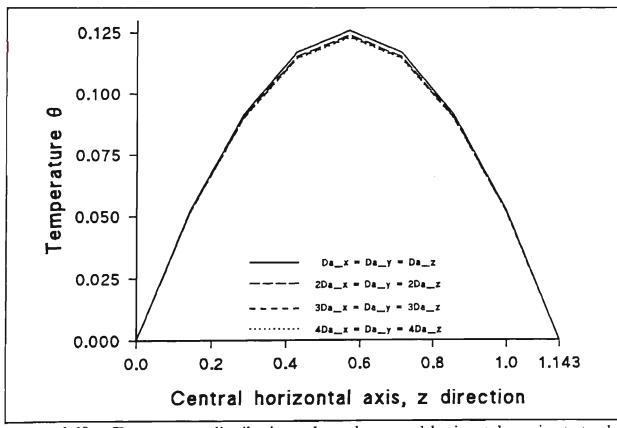


Figure 6.68 Temperature distributions along the central horizontal z axis at steady state for horizontally laid asparagus, adiabatic floor.

6.3.2 Vertically Laid Pack

In packed bed convective heat transfer processes significant differences are expected to occur when vertically packed beds and horizontally packed beds are used. The results presented in this section are for vertically laid carrots and asparagus, as in the horizontally laid pack, four different relationships between the components of permeability were used, for this case they were: $Da_x = Da_y = Da_z$; $Da_x = 2Da_y = 2Da_z$; $Da_x = 3Da_y = 3Da_z$; $Da_x = 4Da_y = 4Da_z$. The boundary conditions for this study are identical to those used for the horizontally laid pack.

The results of this numerical experiment are presented in identical sequence to the horizontally laid carrots and asparagus and Figure 6.69 throught to 6.88 encompass the entire set of results.

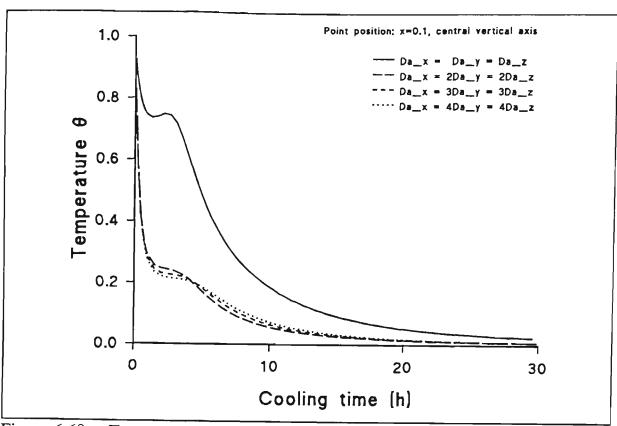


Figure 6.69 Temperature versus time curves for vertically laid carrots, adiabatic floor.

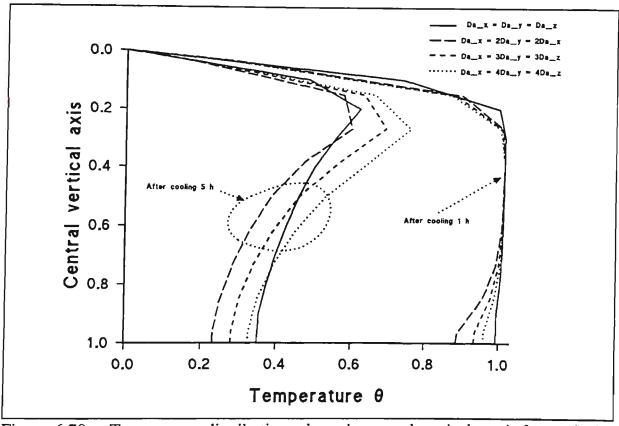


Figure 6.70 Temperature distributions along the central vertical x axis for vertically laid carrots, adiabatic floor.

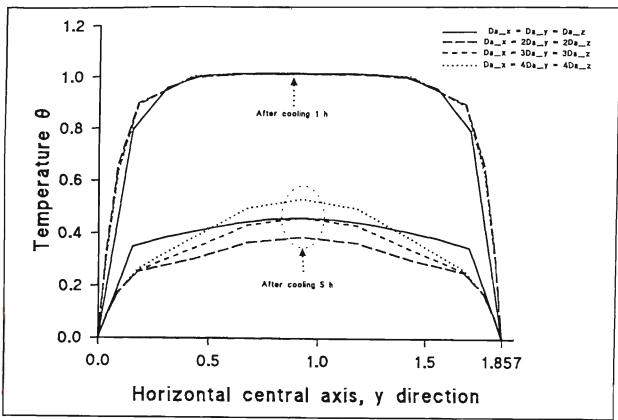


Figure 6.71 Temperature distributions along the central horizontal y axis for vertically laid carrots, adiabatic floor.

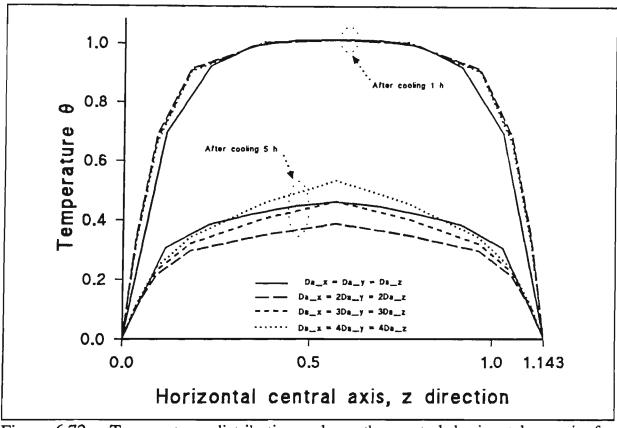


Figure 6.72 Temperature distributions along the central horizontal z axis for vertically laid carrots, adiabatic floor.

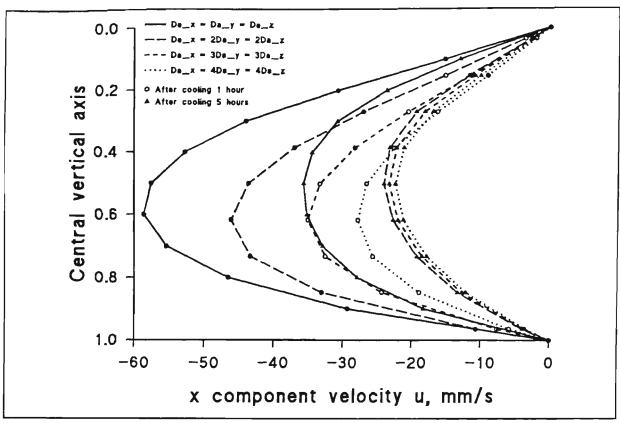


Figure 6.73 x-component of velocity, u, distributions along central vertical x axis for vertically laid carrots, adiabatic floor.

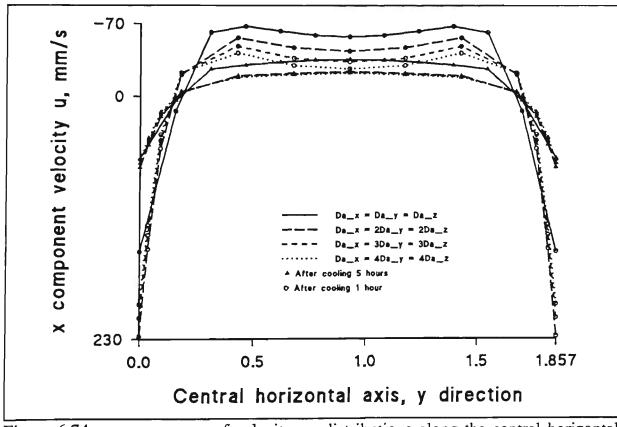


Figure 6.74 x-component of velocity, u, distributions along the central horizontal y axis for vertically laid carrots, adiabatic floor.

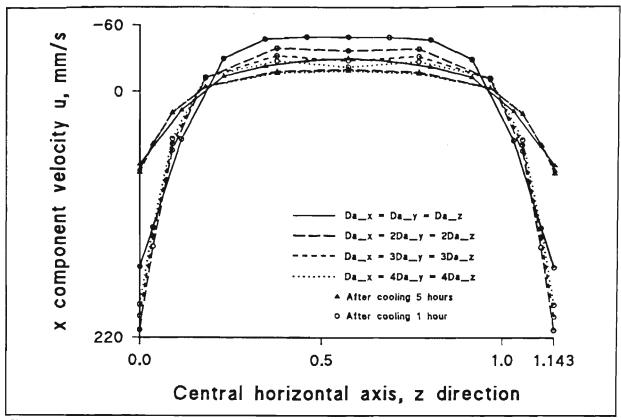


Figure 6.75 x-component of velocity, u, distributions along the central horizontal z axis for vertically laid carrots, adiabatic floor.

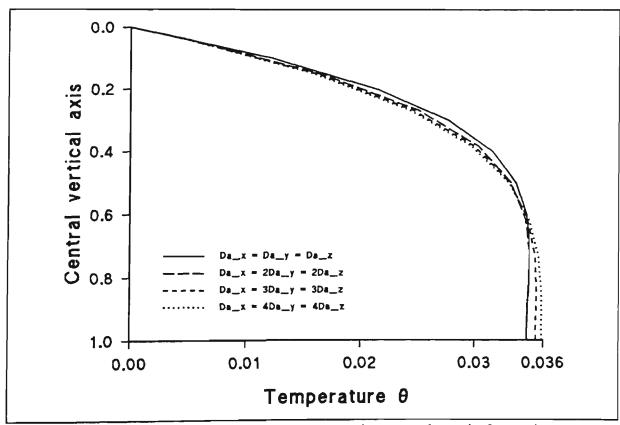


Figure 6.76 Temperature distributions along the central vertical x axis at steady state for vertically laid carrots, adiabatic floor.

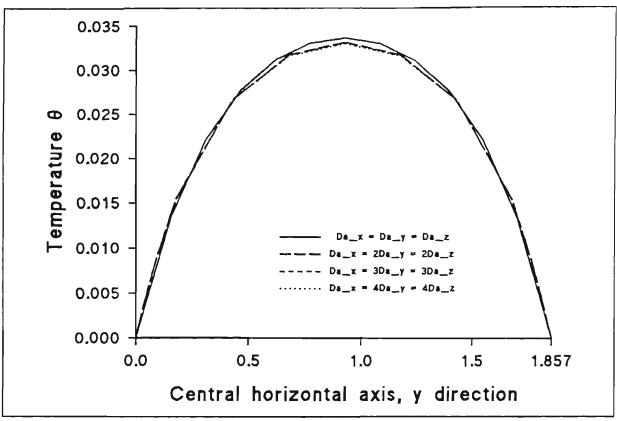


Figure 6.77 Temperature distributions along the central horizontal y axis at steady state for vertically laid carrots, adiabatic floor.

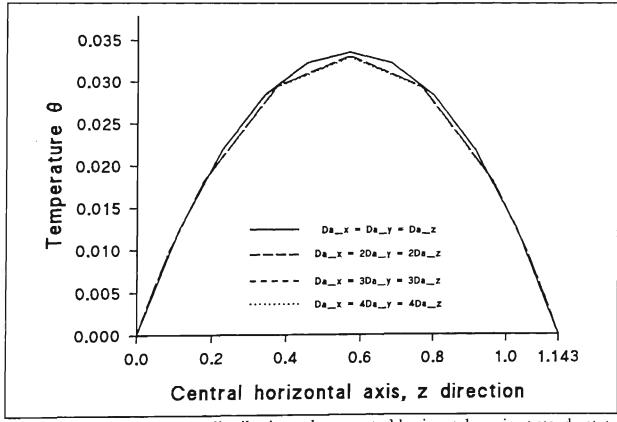


Figure 6.78 Temperature distributions along central horizontal z axis at steady state for vertically laid carrots, adiabatic floor.

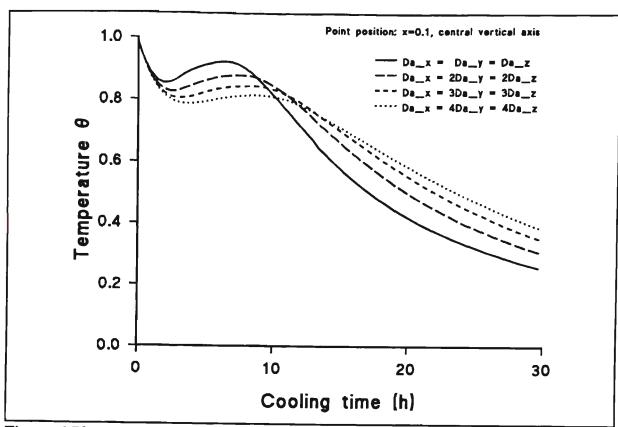


Figure 6.79 Temperature versus time curves for vertically laid asparagus, adiabatic floor.

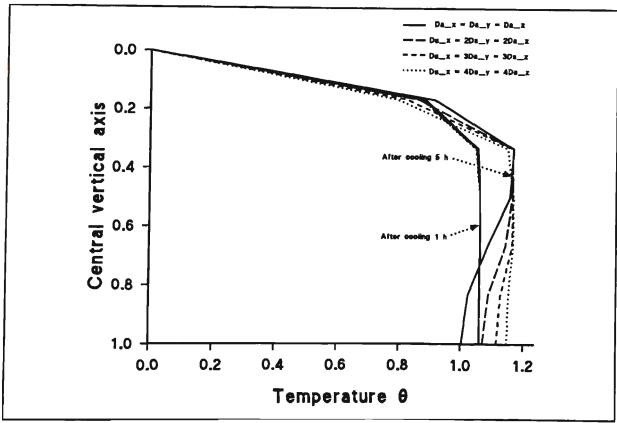


Figure 6.80 Temperature distributions along the central vertical x axis for vertically laid asparagus, adiabatic floor.

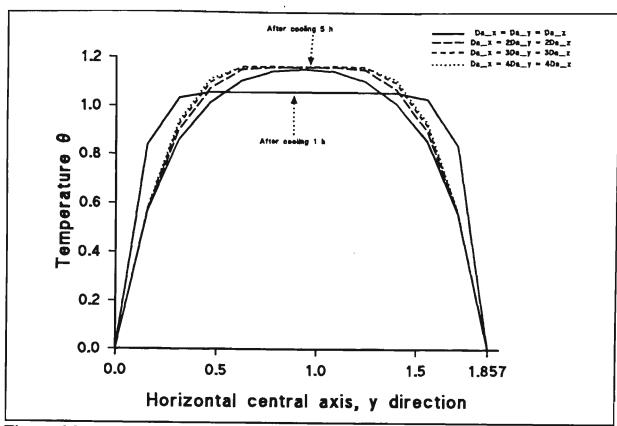


Figure 6.81 Temperature distributions along the central horizontal y axis for vertically laid asparagus, adiabatic floor.

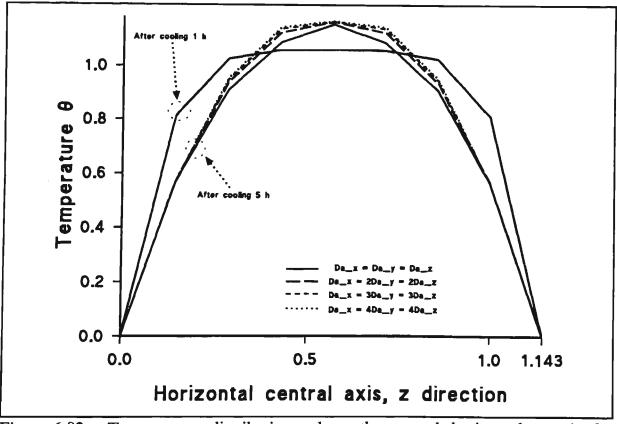


Figure 6.82 Temperature distributions along the central horizontal z axis for vertically laid asparagus, adiabatic floor.

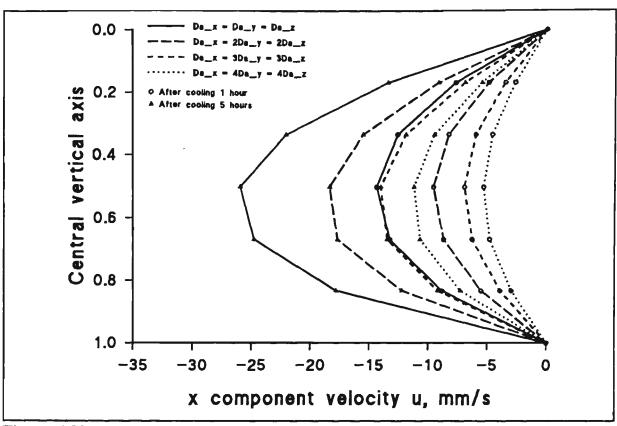


Figure 6.83 x-component of velocity, u, distributions along the central vertical x axis for vertically laid asparagus, adiabatic floor.

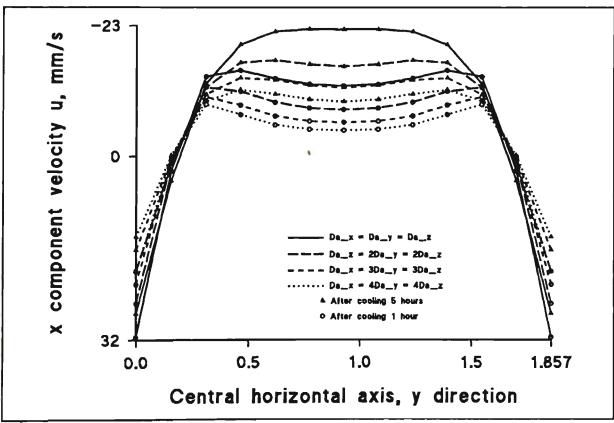


Figure 6.84 x-component of velocity, u, distributions along the central horizontal y axis for vertically laid asparagus, adiabatic floor.

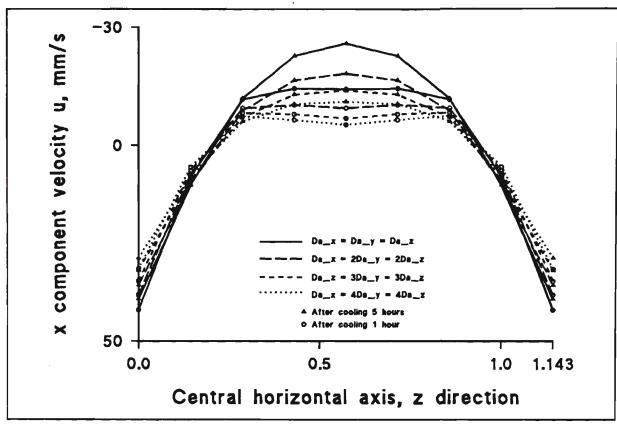


Figure 6.85 x-component of velocity, u, distributions along the cental horizontal z axis for vertically laid asparagus, adiabatic floor.

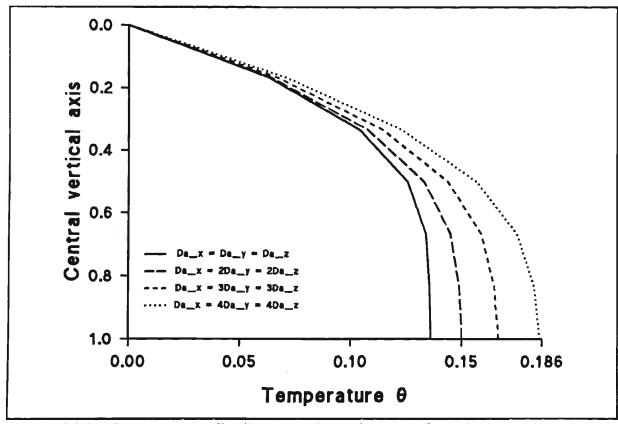


Figure 6.86 Temperature distributions along the central vertical x axis at steady state for vertically laid asparagus, adiabatic floor.

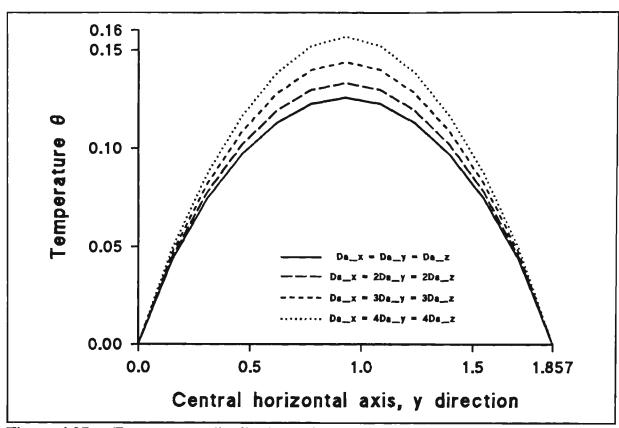


Figure 6.87 Temperature distributions along the cental horizontal y axis at steady state for vertically laid asparagus, adiabatic floor.

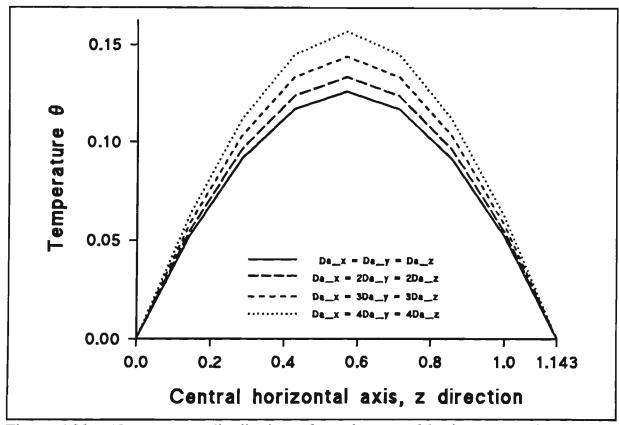


Figure 6.88 Temperature distributions along the central horizontal z axis at steady state for vertically laid asparagus, adiabatic floor.

CHAPTER 7

DISCUSSION

7.1 Numerical Model

In bringing the numerical model to an effective state, firstly the formulation of the underlying principles governing observed phenomena in cooling or heating of stored agricultural produce was accomplished. As distinct from most other established practice, the propositions advanced in this study were concerned with treating transient three-dimensional natural convection in stored respiring produce, as that in a confined porous media with internal heat generation and isotropic or orthotropic permeability. Secondly, the solution of the set of non-linear partial differential equations developed to describe the heat transfer process in packed agricultural produce was obtained numerically, using the method of false transient and the Samarskii-Andreyev implicit alterative direction iteration scheme, as outlined previously. Finally, the model was evaluated and so far as possible compared with other work before applying it to a number of practical applications. It was found the convergence, accuracy and computing time required to obtain solutions depended on a number of factors. These included: mesh type, grid size, time step, false transient parameters, convergence criterion, internal heat source function and container size.

Results obtained using the model were compared with the numerical and experimental results presented by Beukema (1980, 1983), and shown in Chapter 5; the comparison was made using the same internal heat generation, physical property values and boundary conditions.

The results were in good agreement, but Beukema's model does not include a temperature dependent respiratory heat generation function, so realistic comparisons with our results for isotropic fruits and vegetables were not possible. In fact, we were unable to find other work with which to compare our numerical results. This study has provided a valuable perception of the problems associated with the storage and distribution of agricultural produce, but until more detailed information on permeability and respiration rates are available, and the computed numerical results are borne out reasonably well experimentally, we should at the present stage of its development, treat the results obtained with a degree of reserve. In the following sections the results of the study are discussed and ideas for further research are suggested.

7.2 Temperature Distribution

The cooling processes for apples and Brussels sprouts in a standard container with adiabatic or isothermal floor are shown in Figure 6.1, 6.13, 6.25 and 6.37. As expected the temperature changing profiles were different. With isothermal floor the temperatures dropped faster at corresponding positions than those with adiabatic floor. It indicated that the isothermal floor improved the cooling process. The difference of these boundary conditions affected most on the temperature distributions in the lower part of the container, as shown in Table 7.1.

The difference at the bottom, x=0.964, reached up to 80%. At the centre, x=0.5, there was only about 0.02-2.5% difference in temperature between these two boundary conditions. Air was cooled by the side walls and moved downward to the bottom. With the adiabatic floor,

Table 7.1 Comparison of temperature values along the central vertical axis for apples and Brussels sprouts.

| Position x | $\theta_{\text{app_adb}}$ | $\theta_{	ext{app_iso}}$ | $\theta_{\text{Bral_adb}}$ | $\theta_{\tt Bral_iso}$ |
|------------|----------------------------|---------------------------|-----------------------------|--------------------------|
| 0.0360 | 0.3490 | 0.3473 | 0.2871 | 0.2869 |
| 0.1520 | 0.9570 | 0.9549 | 0.8966 | 0.8963 |
| 0.2680 | 1.0123 | 1.0104 | 1.0234 | 1.0232 |
| 0.3840 | 1.0055 | 1.0008 | 1.0340 | 1.0338 |
| 0.5000 | 1.0048 | 0.9795 | 1.0342 | 1.0328 |
| 0.6160 | 1.0017 | 0.9308 | 1.0339 | 1.0251 |
| 0.7320 | 0.9828 | 0.8279 | 1.0331 | 0.9862 |
| 0.8480 | 0.9457 | 0.6260 | 1.0307 | 0.8193 |
| 0.9640 | 0.8574 | 0.1605 | 1.0238 | 0.2411 |

- Note: 1. θ_{app_adb} = temperature of apples with adiabatic floor;
 - 2. θ_{app} is $\theta_{\text{app}} = \theta_{\text{app}} = \theta_{\text{app}}$ temperature of apples with isothermal floor;
 - 3. θ_{Bral} and θ_{Bral} = temperature of Brussels sprouts with adiabatic floor;
 - 4. $\theta_{Brsl iso}$ = temperature of Brussels sprouts with isothermal floor;
 - 5. The values here were obtained at 1 hour cooling time.

the cold air was first warmed up by the produce before it reached the central region of the lower part, thus a small temperature difference between air and produce resulted. With the isothermal floor, when air moved into the central area, it was still cooled by the cold floor and this enabled the air temperature to be lower than of the produce, even in the central area near the bottom. But when the air left the cold bottom to move up, it was heated to near the produce's temperature. This is why there was a big difference in the bottom area and a small one in the central and upper area when adiabatic and isothermal floor were introduced. There was a overall improvement when using the isothermal floor but the temperature behaviour in the central and upper area were quite similar.

When the steady state was reached, the temperature profiles were also different. With the adiabatic floor, the highest temperature was located at the bottom centre. With the isothermal floor the highest temperature was lower than that of the adiabatic floor and was located at the centre of the container.

These results suggest that in cooling practice, attention should be paid to the central and upper area where produce are not easily cooled for both adiabatic and isothermal floor conditions. While in storage practice, if an adiabatic floor is used, the produce at the bottom might undergo damage most easily.

An interesting lower temperature decrease after cooling for a period time can be observed at upper positions, as shown in Figures 5.2, 5.3, 6.1, 6.13, 6.25 and 6.37. This can be explained as follows. At the beginning of cooling, the temperature differences in the container were small and thus natural convection was weak. Heat transfer could be mainly attributed to conduction. A temperature rise, due to the internal heat generation took place in the central area along with a rapid temperature drop near the cold walls. This process could last hours and led to a significant temperature difference as the natural convection developed completely. The air flowed downwards near the cold walls and upwards in the central area in the container. The rising air was warmed resulting in heat transport from the centre or bottom to the upper part of the container.

The respiration heating also had a significant effect on temperature behaviour. Brussels sprouts have a much higher rate than apples do. It also took much longer time to cool down to the same temperature level. As a comparison with Figure 6.25 and 6.37 we can find that at x=0.268, it took about a hour to cool apple to 6°C and about 18 hours for Brussels sprouts. The temperatures for Brussels sprouts at steady state were much higher than those for apples. This is only because of the high heating rate.

With the symmetric system, the temperature distributions were also symmetric as shown in

Appendix C. The contour map of the temperature distribution shows a clear view of the temperature field and its changing progress inside the container.

7.3 Velocity Distribution

Velocity distribution is relative to temperature changing. As shown in Figures 6.1, 6.2, 6.13, 6.14, 6.25, 6.26, 6.37 and 6.38, both rapid temperature changes and high velocity happened within the same time period. When the temperature difference was large, the velocity was also large. This is because with large temperature differences the buoyant force was also large, thus air movement was strong. The strong air movement inside the container started at a certain time after cooling commenced, about 1.0 hour for apples having an adiabatic floor, and reached its maximum value later, about 1.5 hours for apples. In the lower part of the container, velocity first reached its peak value, then those in the central and upper part. It indicates that the commodities in the bottom would be cooled first. This was also reflected in the temperature distribution figures. After a period of cooling, the temperature difference inside the box was small again and thus the velocity became small and uniform.

As shown in figures of x-component of velocity along the central horizontal axes, the downward air flows were limited to a narrow layer near the cold walls. Between the central upward air flow and the downward air flow, the zero velocity u zones were very small and did not change their positions much.

The velocity value near the side walls were greater than those in the centre. This is because that the net mass flow through the plane must be zero. Thus the downward flow rate should

be equal to the upward flow rate. With a lager area surface, the velocity in central area should be smaller. It is found that the velocity profile is quite even within the central area. This means that the temperature in it must be even within the same horizontal plane. Figure 6.4 and 6.5 show the same results. Contour maps of velocity distribution inside the container are shown in Appendix C.

The differences in velocity profiles between adiabatic and isothermal floor were small. This is because in both conditions, the air flow patterns were similar. Air was cooled by sidewalls and moved downward near the walls, then it was warmed and moved upward in the central area. When warm air moved away from the bottom, the space was filled by cold air when a isothermal floor was presented, or warm air when adiabatic floor was used.

Appendix C provides a view of the velocity distribution in central planes. At the top of the container, air moved diverging from the centre while at bottom air moved converging to the centre.

7.4 Nusselt Number

As described in last section, strong air movement happened near the side-walls. Strong heat transfer by convection should also happen within this zone. The convection phenomena in this zone could be a good indication to identify the starting, developing and ending of natural convection inside the container. As defined in Chapter 3, Nusselt numbers are used to describe the natural convection occurring on the surface. When $Nu \le 1$, it implies that there is no convection.

Figures 6.9, 6.24, 6.36 and 6.48 display the average Nusselt numbers' change with time on side-walls and top and bottom. At the beginning of cooling process, Nu had large values. Thus heat transfer by convection played a main role. When cooling reached a certain step, Nu numbers dropped to a low level. This indicated that due to the fact that the temperature differences were small, natural convection was weak and conductive heat transfer was important at this stage.

7.5 Effects of Permeability

7.5.1 Isotropic Permeability

Permeability has an significant effect on natural convection in porous media. As shown in Figure 7.1, the temperature profiles were different when isotropic permeability changed. The larger the permeability, the faster the temperature changed and the less time was needed to cool down the produce. This was because that when permeability increased, the flow resistance inside the packed bed decreased. Air moved more freely thus the convection was enhanced. On the other hand, high permeability also means the packed bed may have a high porosity enabling more space for air and less space for the produce. The heat capacity and the power of the internal heat sources may also be reduced. Thus the packed bed can be cooled quickly.

7.5.2 Orthotropic Permeability

Figure 6.49 to 6.58 show the result of horizontally laid carrots in the package and the results for horizontally laid asparagus are presented in Figure 6.59 to 6.68.

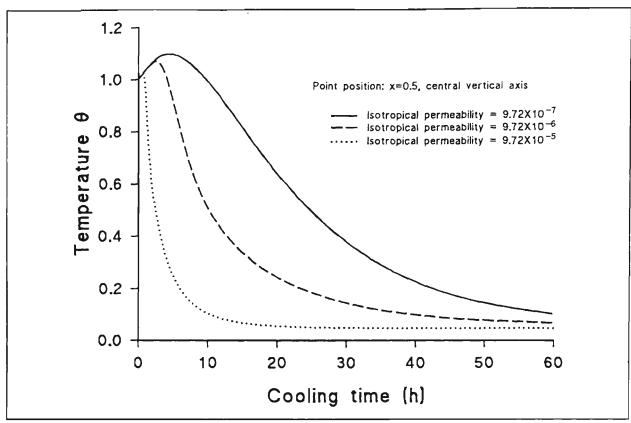


Figure 7.1 Temperature change versus time at central point of the container under different isotropic permeability.

For horizontally laid produce, the results indicate that the cooling process was not significantly affected by the different permeability relationships tried. The temperature distributions were also similar to each other, however slight differences in the velocity fields were observed. Velocity increased when the departure from isotropy increases. When produce were packed horizontally, for example, the axes of produce were parallel to y direction, air channels were formed in y direction. Thus resistance of air movement in y direction was reduced. When natural convection occurred inside the package, as described before, at top of the container, air flowed out from central area to side-walls area and at bottom flowed back to the central from outside region. Horizontally laid pattern improved the air flow in y direction in top and bottom area, but did not improve much in z direction. With no vertical channel formed the vertical air flow did not increase its velocity either.

When produce were packed vertically, vertical channels were formed. Thus resistance in x direction decreased. The downward air flow near side-walls and upward air flow in the central area were enhanced. In natural convection, vertical air movement plays a very important role in heat transfer. Due to the vertical air movement enhancement, the cooling processes were also improved, shown in Figure 6.69 to 6.78 for vertically laid carrots. Because the cooling process was more efficient, the temperature differences in the produce were smaller in the non-isotropic than those in the isotropic arrangements. The velocity was also smaller due to a smaller temperature difference.

Figure 6.79 to 6.88 show the results for vertically oriented asparagus. The vertical package did not show much difference from the isotropic results, shown in Figure 7.2. In the late cooling stage and the steady state, the isotropic package showed a better result. This is because when choosing different relations of permeability in κ , κ , and κ direction, permeability in κ direction, κ_{κ} , was set to a constant value, forcing κ_{κ} , and κ_{κ} smaller when the differences between κ_{κ} , κ_{κ} and κ_{κ} increasing. A low value of κ_{κ} and κ_{κ} implied that the resistance for air movement in κ and κ directions increased. Figure 7.3 shows the results when κ_{κ} and κ_{κ} were set to a fixed value but κ_{κ} increased to perform the horizontally laid effect. The cooling process was improved with κ_{κ} increasing. When κ_{κ} was larger than a certain value, the cooling process did not improve. This may be explained as when κ_{κ} was large enough, resistances in κ and κ directions became critical. Thus, increasing κ_{κ} would not improve the convection unless κ_{κ} and κ_{κ} were improved.

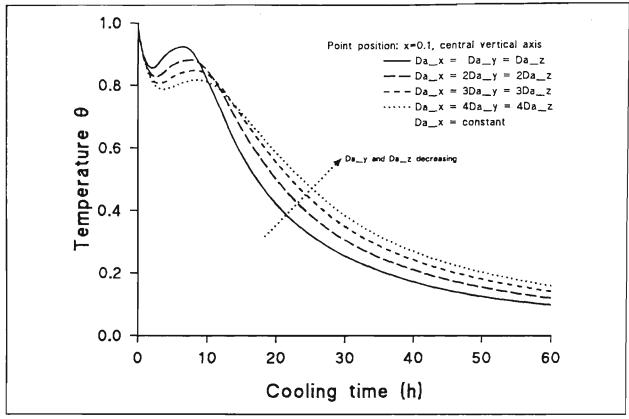


Figure 7.2 Temperature versus time curves for vertically laid asparagus, adiabatic floor. Resistance in y and z direction increasing.

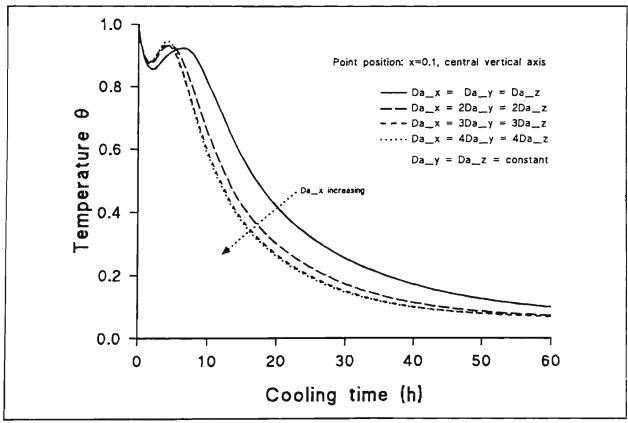


Figure 7.3 Temperature versus time curves for vertically laid asparagus, adiabatic floor. Resistance in x direction decreasing.

7.6 Respiration Effects on Container Size

A comparison of cooling processes for apples in a large container with and without respiration is shown in Figure 7.4. Because the respiration rate for apples was small, even at high temperatures, the temperature differences shown in figure 7.4 were also small. At steady state, the temperature was uniform. Without respiration heat, the temperature of the produce finally equilibrated to the environmental temperature $\theta = 0$. With respiring heating, the final temperature was still higher than the environmental temperature.

As discussed later, a large container is not suitable for cooling or storing produce having a high respiration rate. But even for a small container, the inclusion of respiration heat produces a significant temperature difference, as show in Figure 7.5.

Currently many different sized containers are used to store fruits or vegetables. When produce is harvested, the field heat should be removed as quickly as possible and usually this is done within a few hours. Delays between harvesting and cooling produce are certain to increase deterioration when ambient temperatures are high. Figure 7.6 and 7.7 show the numerical results of the cooling process for apples and Brussels sprouts in different size boxes. It is evident that the bigger the size of the box, the higher is the temperature reached and the longer is the time needed to cool the produce to steady state. It may be clearly seen that a small size container is better suited for rapid cooling than large boxes provided the cold walls can be maintained.

Referring to Figure 7.7, when a large size container was used to cool and store high

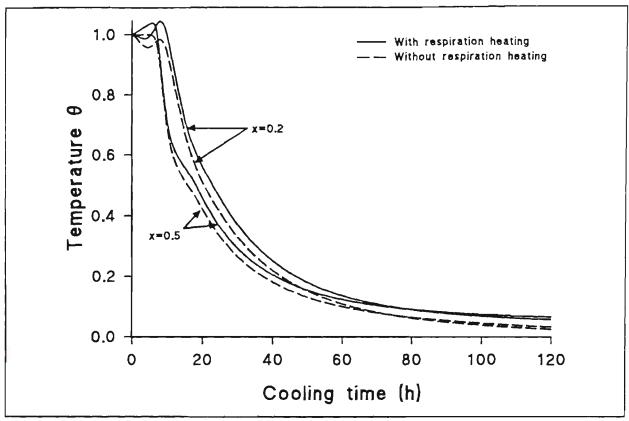


Figure 7.4 Temperature changing with time at central vertical axis, container size: 0.5 x 1.2 x 1.0 m, Apples, adiabatic floor

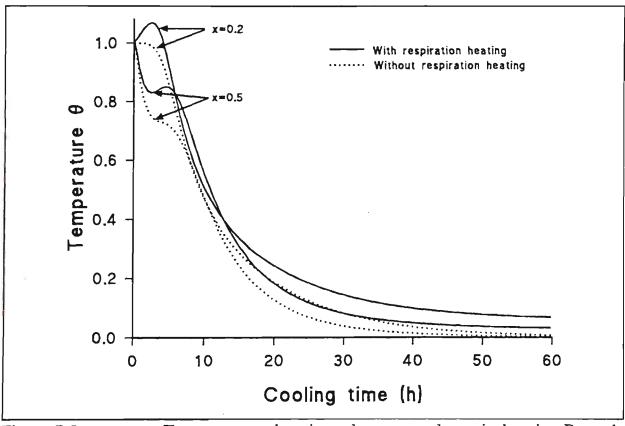


Figure 7.5 Temperature changing along central vertical axis, Brussels sprouts, container size: 0.28 x 0.52 x 0.32 m

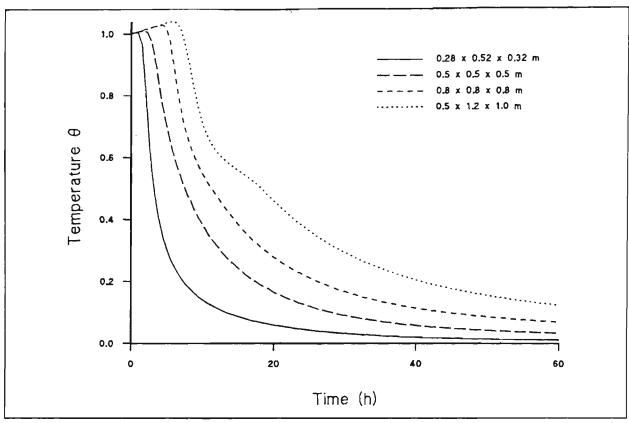


Figure 7.6 Effect of different size boxes on the cooling process for apple

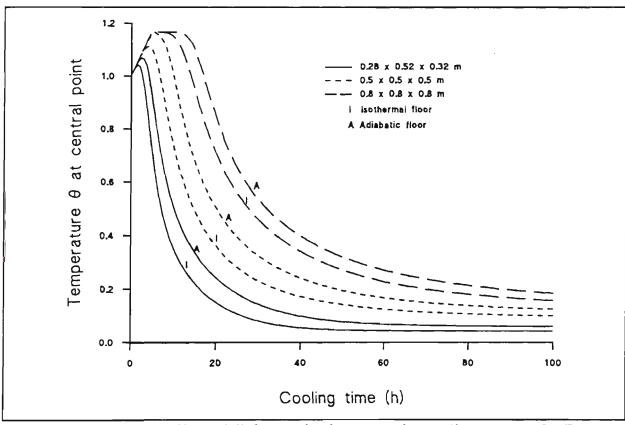


Figure 7.7 Effect of different size boxes on the cooling process for Brussels sprouts

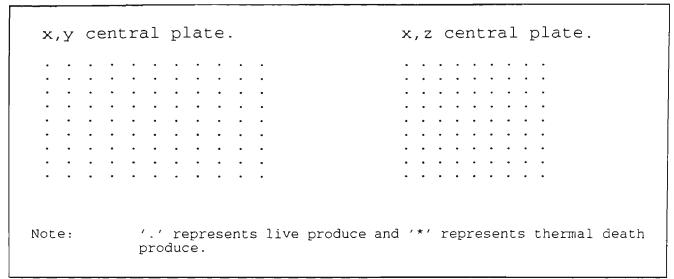


Figure 7.8 Positions of live and thermal dead Brussels sprouts on two central plates when reaching steady state. Box size: 0.28x0.52x0.32m, adiabatic floor, initial temperature 30°C.

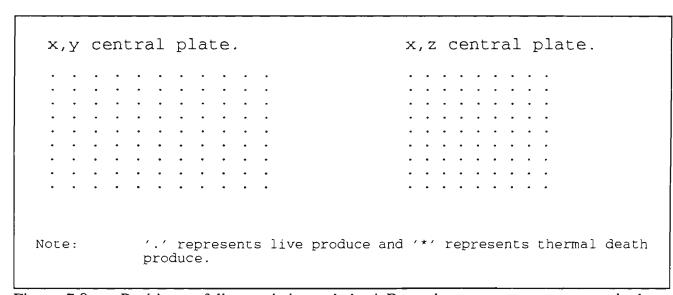


Figure 7.9 Positions of live and thermal dead Brussels sprouts on two central plates when reaching steady state. Box size: 0.28x0.52x0.32m, isothermal floor, initial temperature 30°C.

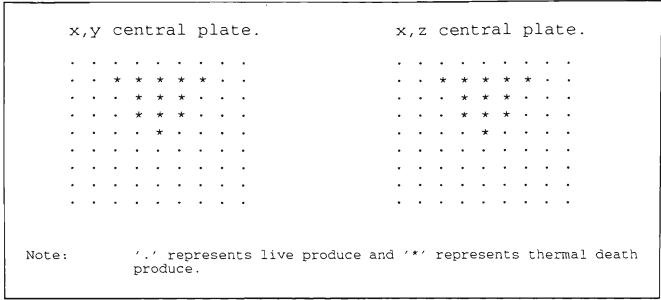


Figure 7.10 Positions of live and thermal dead Brussels sprouts on two central plates when reaching steady state. Box size: 0.5x0.5x0.5m, adiabatic floor, initial temperature 30°C.

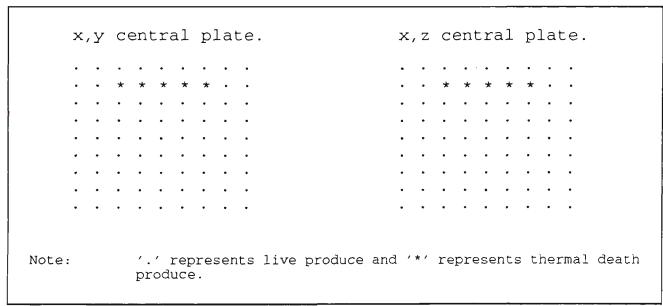


Figure 7.11 Positions of live and thermal dead Brussels sprouts on two central plates when reaching steady state. Box size: 0.5x0.5x0.5m, isothermal floor, initial temperature 30°C.

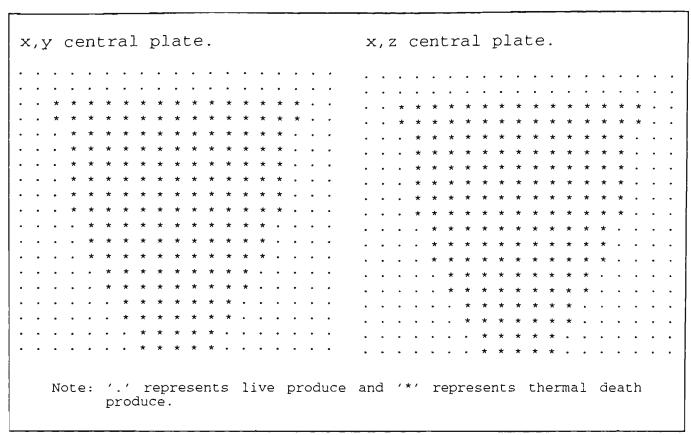


Figure 7.12 Positions of live and thermal dead Brussels sprouts on two central plates when reaching steady state. Box size: 0.8x0.8x0.8m, adiabatic floor, initial temperature 30°C.

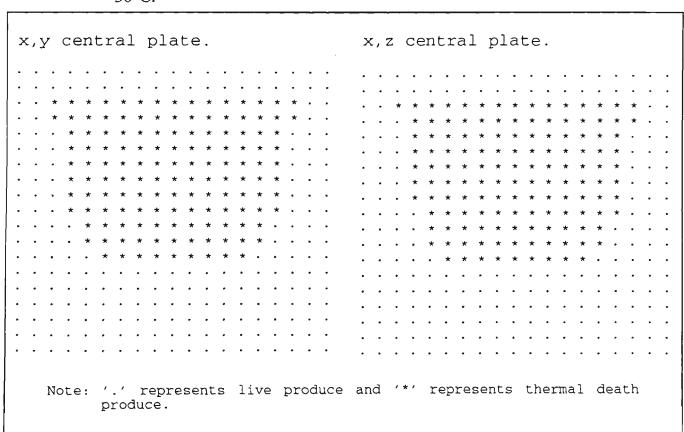


Figure 7.13 Positions of live and thermal dead Brussels sprouts on two central plates when reaching steady state. Box size: 0.8x0.8x0.8m, isothermal floor, initial temperature 30°C.

respiration rate produce, such as Brussels sprouts, a critically high temperature can be reached so that the produce suffers "thermal death". No life activities take place and no heat can be generated after reaching this point. Figure 7.8 to 7.13 display the distribution positions of alive and thermally dead Brussels sprouts after cooling process. When a small size container was used, no thermal death occurred. When using a large container, produce in the central area became thermally dead. Due to the cold top, produce in the surface layer still remained alive. Thus it might not be easy to identify the quality of the produce by just seeing the surface.

Even for the low respiration rate produce such as apple, a small container is still not good enough for efficient cooling to remove the field heat. As shown in Figure 7.6, for a standard $0.28 \times 0.52 \times 0.32$ m box, it took about 8 hours to cool apples from $\theta = 1$ (t=30°C) to $\theta = 0.2$ (t=6°C). With such a long time at high temperature, apples probably suffer from deterioration.

A fast pre-cooling procedure usually is used to remove the field heat efficiently. Different heating rates also had strong effects on temperature at steady state even when the produce was prechilled to 0°C, as shown in Figure 7.14. For example, Brussels sprouts reached a steady state temperature as high as $\theta = 0.06$, ie t=0.18°C and the temperature distribution was not uniform, as shown in Figures 6,25, 6.26 and 6.27. Figure 7.15 reveals the temperature versus time characteristic for stored Brussels sprouts after pre-cooling to 0°C and Figure 7.16 shows the steady state temperature distribution along the central vertical axis, when different sized containers were chosen. The final temperature was high and respiration remains at a relatively strong level, thus demonstrating that Brussels sprouts usually can only be stored for a short time.

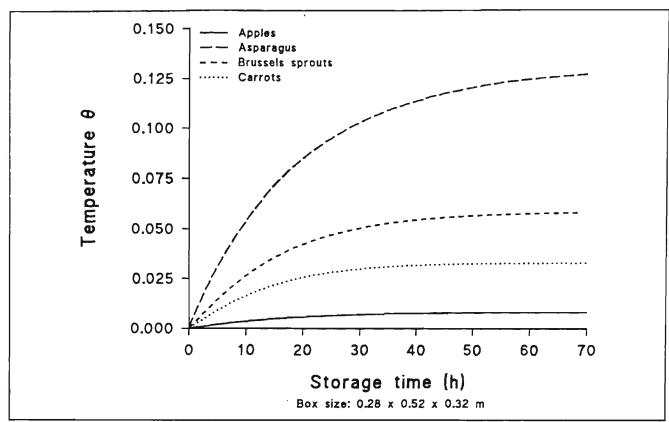


Figure 7.14 Effect of different respiration heating rate on temperature changing at central point of the container, 0.28 x 0.52 x 0.32 m, adiabatic floor, prechilled temperature 0 °C.

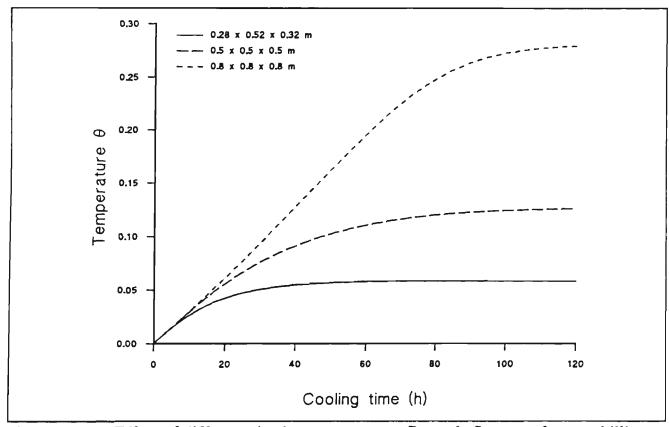


Figure 7.15 Effect of different size boxes on storage Brussels Sprouts after prechilling to 0 °C.

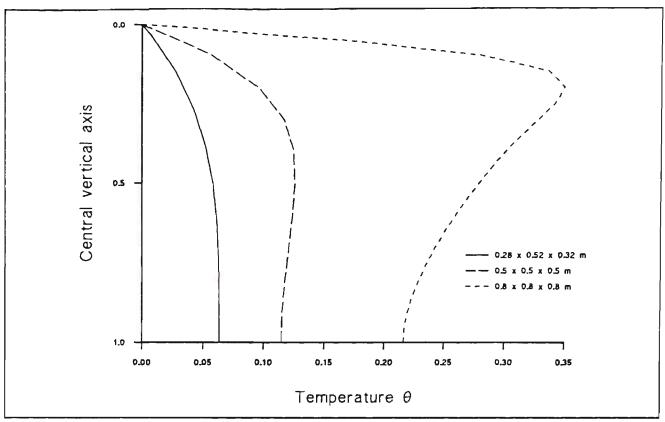


Figure 7.16 Effect of box size on temperature distribution along central vertical axis, Brussels Sprouts, prechilled to 0 °C.

7.7 Suggestions for Further Research

7.7.1 Permeability

Experimentally determined permeability measurements for various fruits and vegetables in of paramount importance and if this information becomes available it would enhance the usefulness of the model.

7.7.2 Respiration Function

Effects should be made to develop methods, based on measurements, of rapidly determining the characteristic temperature dependent respiration function for various commodities. Critical temperature of thermal death, both freezing point and hot point,

for various fruits and vegetables are important to determine the respiration functions in the model.

7.7.3 Transpiration Rate

Foremost of all the improvements which could be made to the model would be to account for transpiration or moisture loss in the produce. The factors influencing transpiration rates are temperature, humidity and barometric pressure in storage or transportation vehicle. A suggestion for doing this would be to incorporate the cooling effect of evaporation by adding an additional negative term to the respiratory heat generation - its form would be "rate of moisture loss × latent heat of vaporization". Also a moisture transfer equation could be considered into the equations group to obtain a mass-heat transfer model.

CHAPTER 8

CONCLUSIONS

- 1. The theory of natural convective heat transfer with internal heat generation as applied to the storage of agricultural or horticultural produce, was extended by successfully incorporation a characteristic temperature dependent respiratory heat generation term.
- 2. A three-dimensional transient model of the natural convective heat transfer processes occurring in stored agricultural produce in closed containers with isotropic or orthotropic permeability and temperature dependent respiratory heating was developed to an effective state.
- 3. In stored produce, heat generated by respiration significantly influences the temperature and velocity distributions. Respiration also affects the final uniform steady state temperature low respiration rates give lower steady state temperatures and smaller temperature differences within the container, whereas higher respiration rates lead to greater steady state temperatures and more non-uniform temperature distributions.
- 4. Container size is an important factor in cooling and storage of agricultural produce.

 Commodities with lower respiration rates may be packed in larger containers, but for higher respiration rate commodities, restrictions on the size of container used may be necessary to avoid high and non-uniform temperatures.

5. The nature of the permeability also affects the natural convective heat transfer process. The results of this study demonstrated that a package pattern which produces lower resistance to flow along the direction of gravity gives more effective heat transfer.

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SOLUTION OF LAPLACE EQUATIONS

In Chapter 3 we have two Laplace equations. One is the scale potential ϕ :

$$\nabla^2 \phi = 0 \tag{3.48}$$

Another is the equation for the x component of vector potential when $k_y = k_z$ and the x axis is along the gravity direction:

$$\nabla^2 \psi_r = 0 \tag{3.87}$$

With their boundary conditions it is found that ϕ is an arbitary constant and $\psi_x = 0$. In this appendix the detailed solution of ϕ is demonstrated.

The solution procedure consists of four steps. Applying the theory of Separation of Variables, we assume that the solution of ϕ exist as products of a function X(x) of x alone, a function Y(y) of y alone and a function Z(z) of z alone, thus we may write $\phi(x,y,z) = X(x)Y(y)Z(z) \tag{A1}$

Step 1

Firstly at eight corners of the enclosure, for example, at (0,0,0), it is simply found that

$$\frac{\partial \Phi}{\partial x}\Big|_{(0,0,0)} = \frac{dX}{dx}\Big|_{x=0} Y(0)Z(0) = 0 \tag{A2}$$

$$\frac{\partial \Phi}{\partial y}\Big|_{(0,0,0)} = \frac{dY}{dy}\Big|_{y=0} X(0)Z(0) = 0 \tag{A3}$$

$$\frac{\partial \Phi}{\partial z}\Big|_{(0,0,0)} = \frac{dZ}{dz}\Big|_{z=0} X(0)Y(0) = 0 \tag{A4}$$

supose that

$$X(0) \neq 0$$
, $Y(0) \neq 0$, $Z(0) \neq 0$ (A5 - A7)

From equations A2 to A4 we have

$$X(0) = c_1, Y(0) = c_2, z(0) = c_3$$
 (A8 - A10)

or,

$$\phi = c_1 c_2 c_3 = C \tag{A11}$$

where ϕ is an arbitrary constant at the corners.

Step 2

We next solve for ϕ on the edges of the enclosure, for example, at x=0 and y=0. At the edge, equation 3.47 becomes one dimensional and can be readily solved. We have

$$\frac{\partial^2 \Phi}{\partial z^2} = 0 \tag{A12}$$

$$\frac{\partial \Phi}{\partial z} = c_4 \tag{A13}$$

$$\Phi = c_4 z + c_5 \tag{A14}$$

Applying the above results at z=0 and $z=z_0$ in step 1 we find

$$\phi|_{z=0} = c_5 = C \tag{A15}$$

$$\Phi \big|_{z=z_0} = c_4 z_0 + C = C \tag{A16}$$

$$c_4=0$$
, ie, $\phi = c_4 z + c_5 = C$ (A17)

Step 3

Now the results on the edges can be used as the bouldary conditions for solving ϕ on the surfaces, on which equation 3.48 becomes two dimensional, for example, on the surface z=0, we have

$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} = \mathbf{0} \tag{A18}$$

hence

$$X''Y+Y''X=0$$

or

$$\frac{X''}{X} = -\frac{Y''}{Y} \tag{A19}$$

Now the left hand side member of the above equation is independent of y. Hence the right-hand side of it must also be independent of y since it is identically equal to the expression on the left. Similarly each member of the equation must be independent of x. Therefore, being independent of both x and y, each side of the equation must be a constant, say, C^* , we can write

$$\frac{X''}{X} = -\frac{Y''}{Y} = C^*$$
 (A20)

if $C^*<0$, say, $C^*=-\lambda^2$ ($\lambda>0$), we have,

$$X'' = -\lambda^2 X \qquad \Rightarrow \qquad X = a_1 \cos \lambda x + a_2 \sin \lambda x + a_3 \tag{A21}$$

$$Y'' = \lambda^2 Y$$
 \Rightarrow $Y = a_4 \cosh \lambda x + a_5 \sinh \lambda x + a_6$ (A22)

Using the result of step 2, viz,

$$\phi|_{x=0} = X * Y = (a_1 + a_3) * Y = C$$
 (A23)

$$\phi|_{y=0} = X * Y = X * (a_4 + a_6) = C \tag{A24}$$

From these two expressions we can say that both X, Y are constant and their product is equal to C, thus, we have

$$\phi = X * Y = C \tag{A25}$$

if $C^*=0$, then

$$X''=0 \qquad \Rightarrow \qquad X=a_1x+a_2 \tag{A26}$$

$$Y''=0 \qquad \Rightarrow \qquad Y=a_3y+a_4 \tag{A27}$$

Applying the boundary conditions

$$\phi|_{x=0} = C \tag{A28}$$

$$\phi|_{v=0} = C \tag{A29}$$

leads to

$$a_1 = a_3 = 0$$
 $a_2 * a_4 = C$ (A30)

if $C^*>0$, then

$$X'' = \lambda^2 X$$
 \Rightarrow $X = a_1 \cosh \lambda x + a_2 \sinh \lambda x + a_3$ (A31)

$$Y'' = -\lambda^2 Y \qquad \Rightarrow \qquad Y = a_4 \cos \lambda x + a_5 \sin \lambda x + a_6 \tag{A32}$$

Using the result of step 2, viz,

$$\phi|_{x=0} = X * Y = (a_1 + a_3) * Y = C$$
 (A33)

$$\phi|_{y=0} = X * Y = X * (a_4 + a_6) = C$$
 (A34)

From these two expressions we can say that both X, Y are constant and their product is equal to C, thus, we have

$$\mathbf{\Phi} = \mathbf{X} * \mathbf{Y} = \mathbf{C} \tag{A35}$$

Step 4

Now considering ϕ on any z plane, we can use the result of step 3 and since the equation and boundary conditions are exactually the same as those in step 3. We obtain $\phi = C$.

APPENDIX B

THOMAS METHOD FOR SOLVING A TRI-DIAGONAL MATRIX EQUATION

In solving temperature and vector potential fields, an equation set having a tri-diagonal matrix is encountered. The equation set takes the form

$$b_{1}x_{1} + c_{1}x_{2} = d_{1}$$

$$a_{2}x_{1} + b_{2}x_{2} + c_{2}x_{3} = d_{2}$$

$$a_{3}x_{2} + b_{3}x_{3} + c_{3}x_{4} = d_{3}$$
.....
$$a_{j}x_{j-1} + b_{j}x_{j} + c_{j}x_{j+1} = d_{j}$$
.....
$$a_{n-1}x_{n-2} + b_{n-1}x_{n-1} + c_{n-1}x_{n} = d_{n-1}$$

$$a_{n}x_{n-1} + b_{n}x_{n} = d_{n}$$
(B1)

or in a matrix form

$$\begin{bmatrix} b_{1} & c_{1} & & & & & \\ a_{2} & b_{2} & c_{2} & & & & \\ & a_{3} & b_{3} & c_{3} & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ &$$

The idea behind the Gaussian elimination scheme is to manipulate the equations into the form

$$\begin{bmatrix} \beta_1 & c_1 & & & & & \\ & \beta_2 & c_2 & & & & \\ & & \beta_3 & c_3 & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & \\ & & & \\$$

It is then easy to find x_n , since

$$\dot{\beta}_n x_n = \delta_n$$

or

$$x_n = \delta_n / \beta_n \tag{B4}$$

Knowing x_n enables us to find x_{n-1} from

$$\beta_{n-1}x_{n-1} + c_{n-1}x_n = \delta_{n-1}$$

$$or \quad x_{n-1} = \frac{\delta_{n-1} - c_{n-1}x_n}{\beta_{n-1}}$$
(B5)

and x_{n-2} from

$$x_{n-2} = \frac{\delta_{n-2} - c_{n-2} x_{n-1}}{\beta_{n-2}}$$
 (B5a)

and so on.

The question now arises as to how to manipulate the system of equations into the desired form.

Firstly set

$$\beta_1 = b_1 \quad and \quad \delta_1 = d_1 .$$
 (B6)

So the first two equations become

$$\beta_1 x_1 + c_1 x_2 = \delta_1 \tag{B7}$$

$$\beta_1 x_1 + c_1 x_2 = \delta_1$$

$$a_2 x_1 + b_2 x_2 + c_2 x_3 = d_2$$
(B7)
(B8)

Multiply equation (B7) by a_2/β_1

$$a_2 x_1 + \frac{a_2}{\beta_1} c_2 x_2 = \delta_1 \frac{a_2}{\beta_1}$$
 (B7a)

and subtract this result from equation (B8) to get

$$(b_2 - \frac{a_2}{\beta_1}c_2)x_2 + c_2x_3 = d_2 - \delta_1 \frac{a_2}{\beta_1}$$
 (B8a)

Now set $b_2 - \frac{a_2}{\beta_1} c_2 = \beta_2$ and $d_2 - \delta_1 \frac{a_2}{\beta_1} = \delta_2$

So equation (B8a) may be written as

$$\beta_2 x_2 + c_2 x_3 = \delta_2 \tag{B8b}$$

Which is exactly the form we require.

Now consider the equations

$$\beta_2 x_2 + c_2 x_3 = \delta_2$$

$$a_3 x_2 + b_3 x_3 + c_3 X_4 = d_3$$
(B8b)
(B9)

Multiply equation (B8b) by $\frac{a_3}{\beta_2}$ to get

$$a_3 x_2 + \frac{a_3}{\beta_2} c_2 x_3 = \frac{\delta_2}{\beta_2} a_3$$
 (B8c)

Subtracting equation (B8c) from equation (B9) yields

$$(b_3 - \frac{a_3}{\beta_2}c_2)x_3 + c_4x_4 = d_3 - \frac{\delta_2}{\beta_2}a_3$$
 (B9a)

so if
$$\beta_1 = b_3 - \frac{a_3}{\beta_2} c_2$$
 and $\delta_3 = d_3 - \frac{\delta_2}{\beta_3} a_3$

equation (B9) becomes

$$\beta_3 x_3 + c_4 x_4 = \delta_3 \tag{B9b}$$

and so on.

In general we have

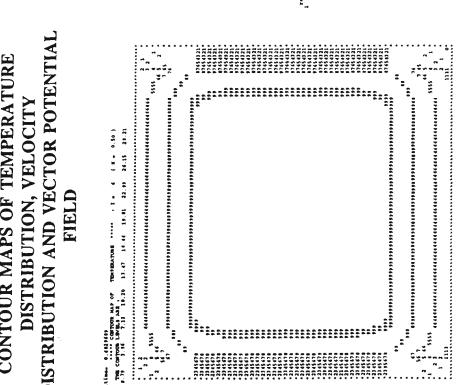
$$\beta_j = b_j - \frac{a_j}{\beta_{j-1}} c_{j-1}$$
 (B10)

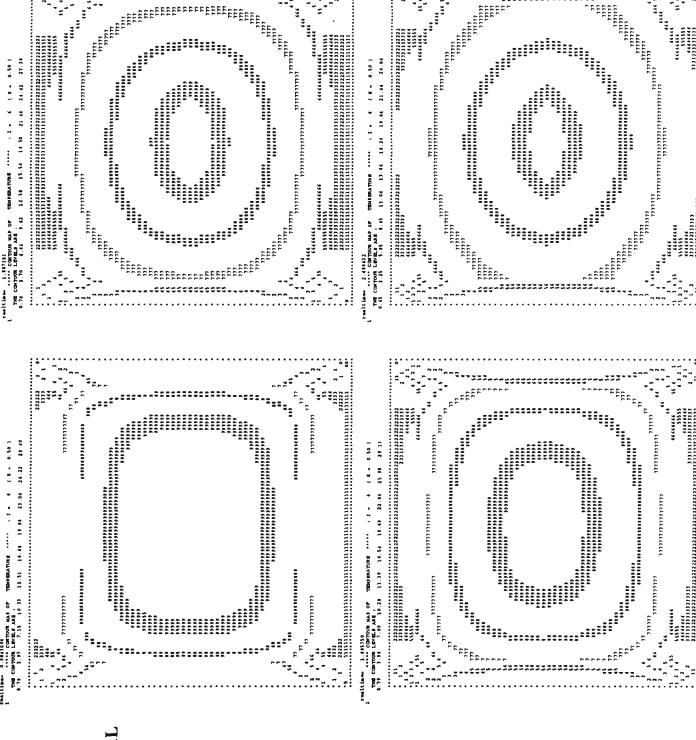
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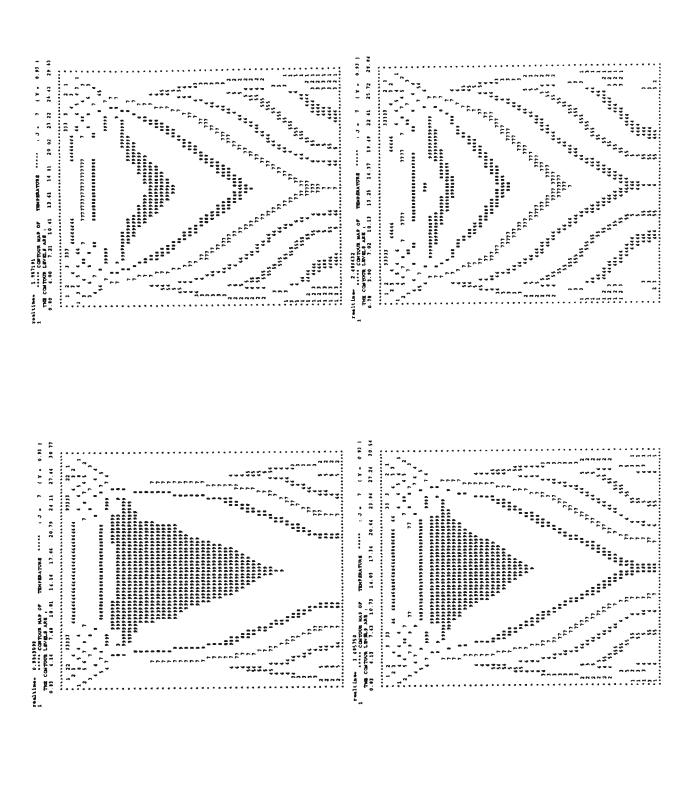
$$\delta_j = d_j - \frac{\delta_{j-1}}{\beta_{j-1}} a_j \tag{B11}$$

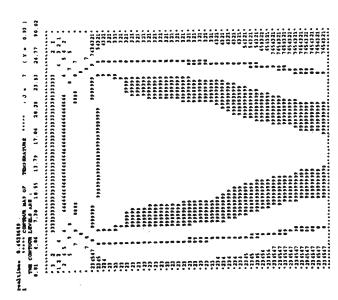
remembering that we have set $\beta_1 = b_1$ and $\delta_1 = d_1$, therefore all the β and δ can be found and thus all the x_i can be found.

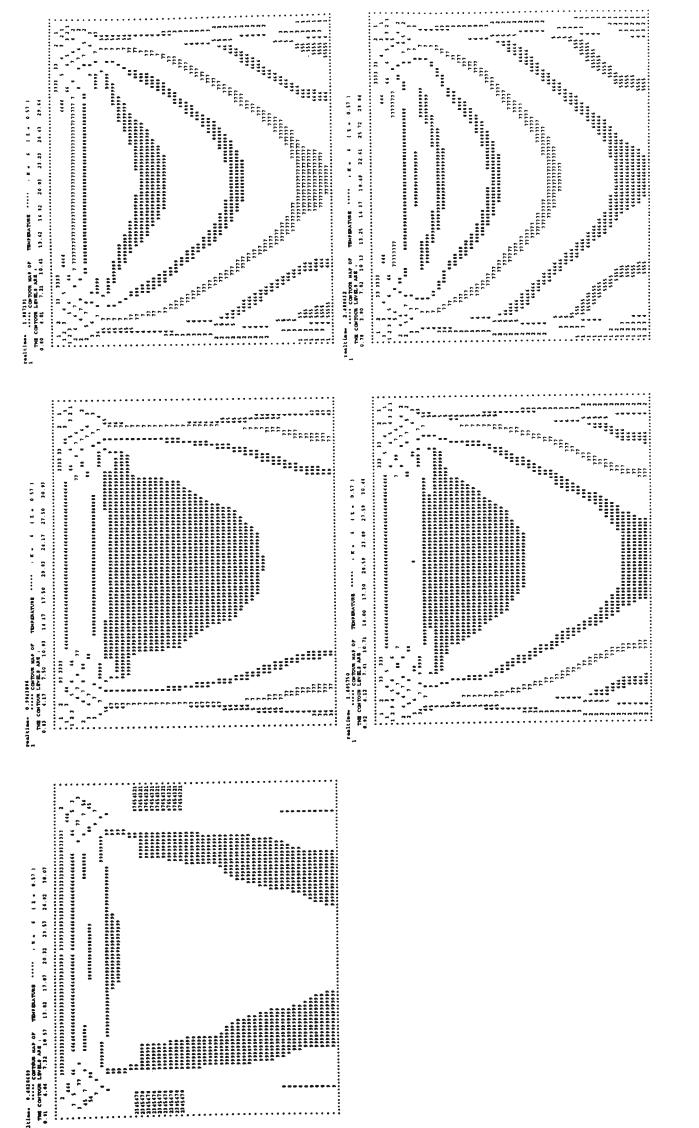
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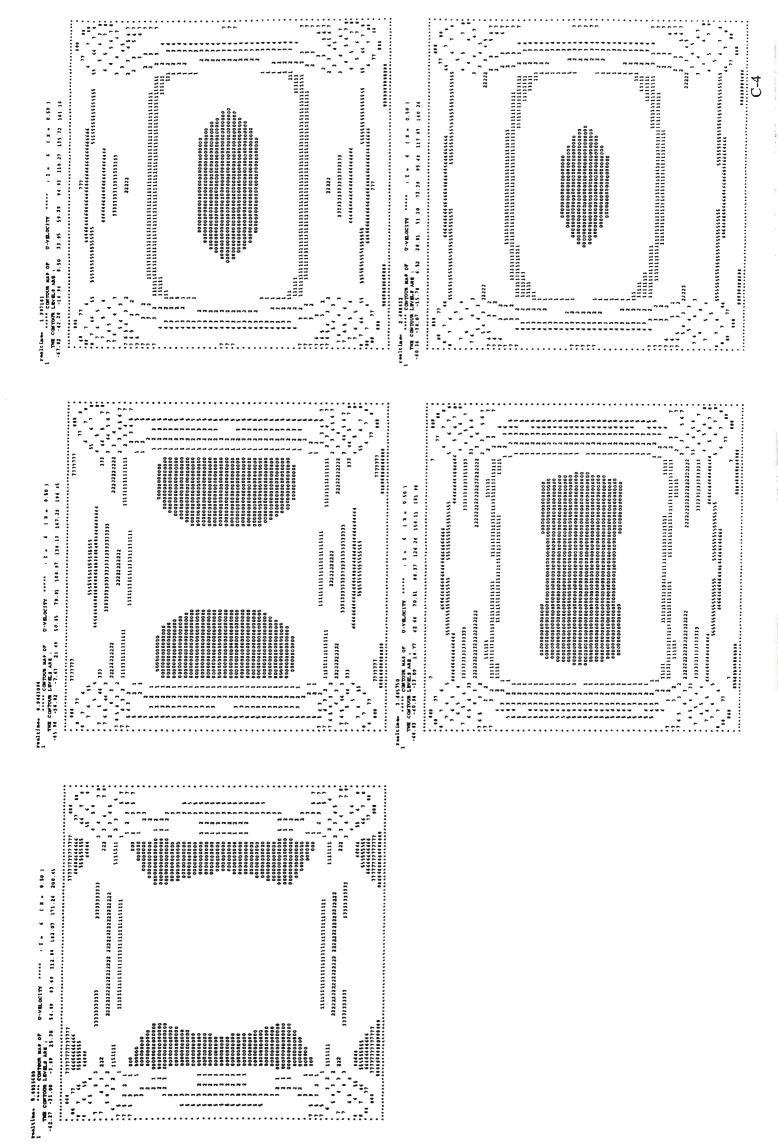


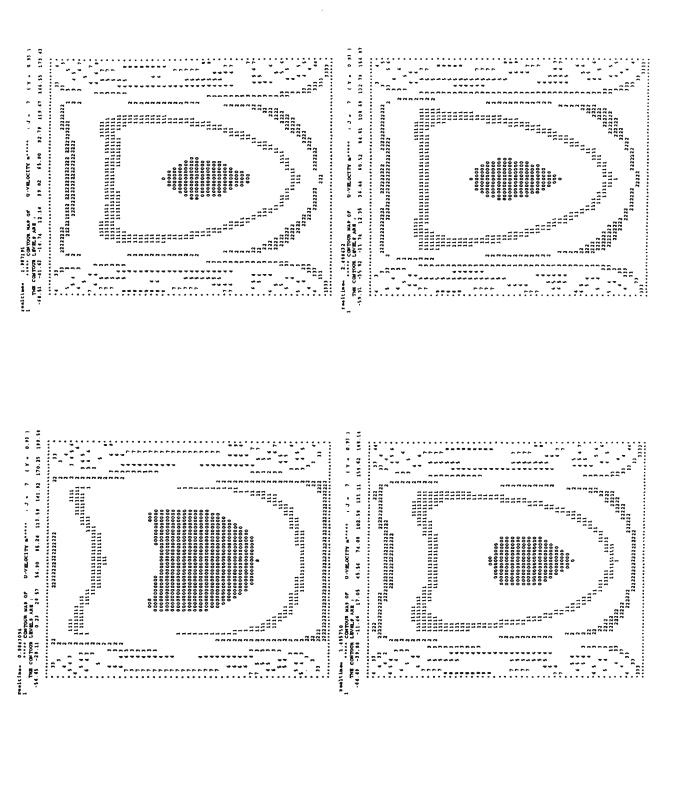


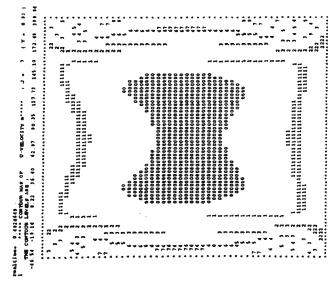


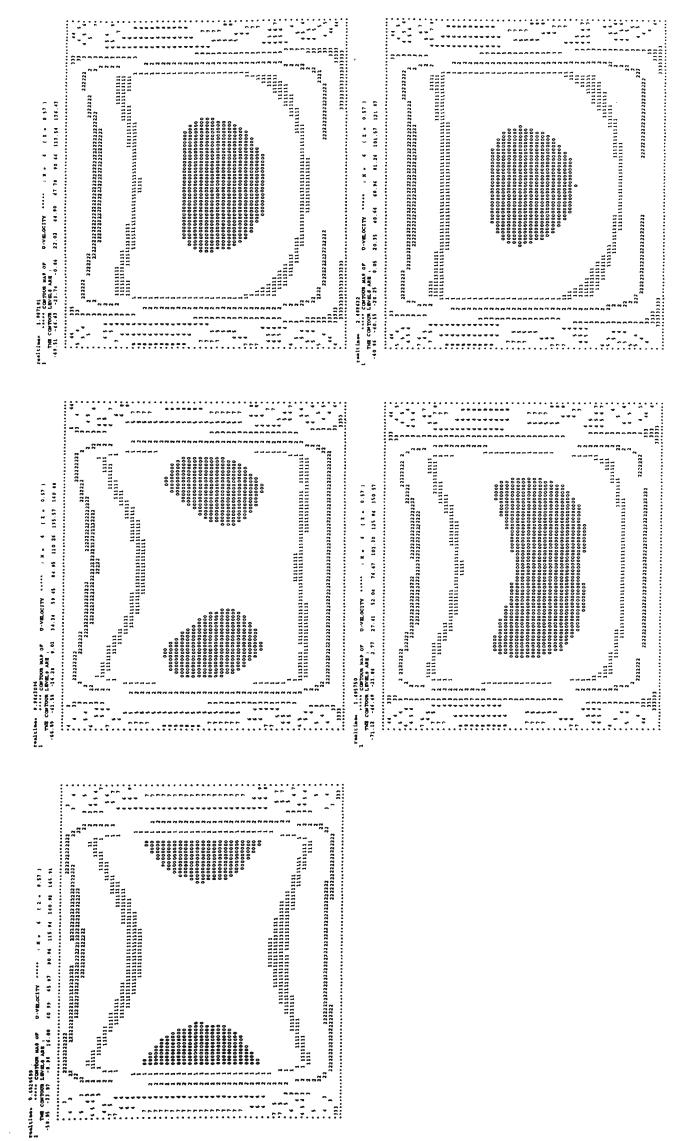


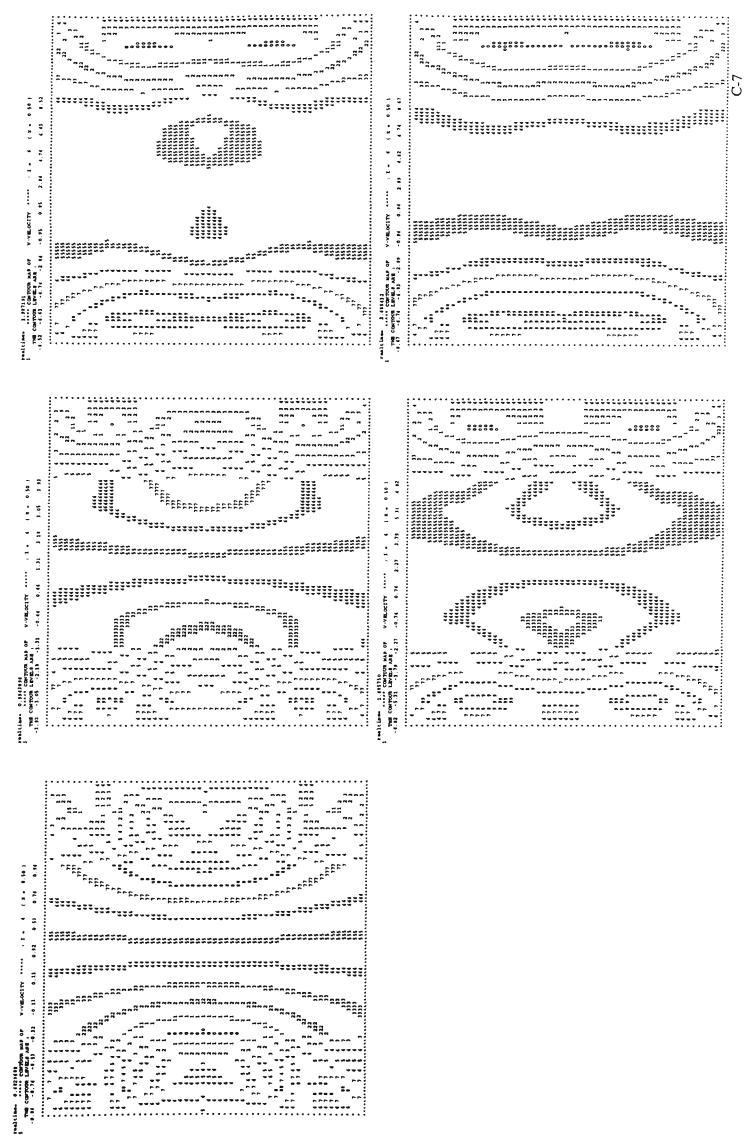


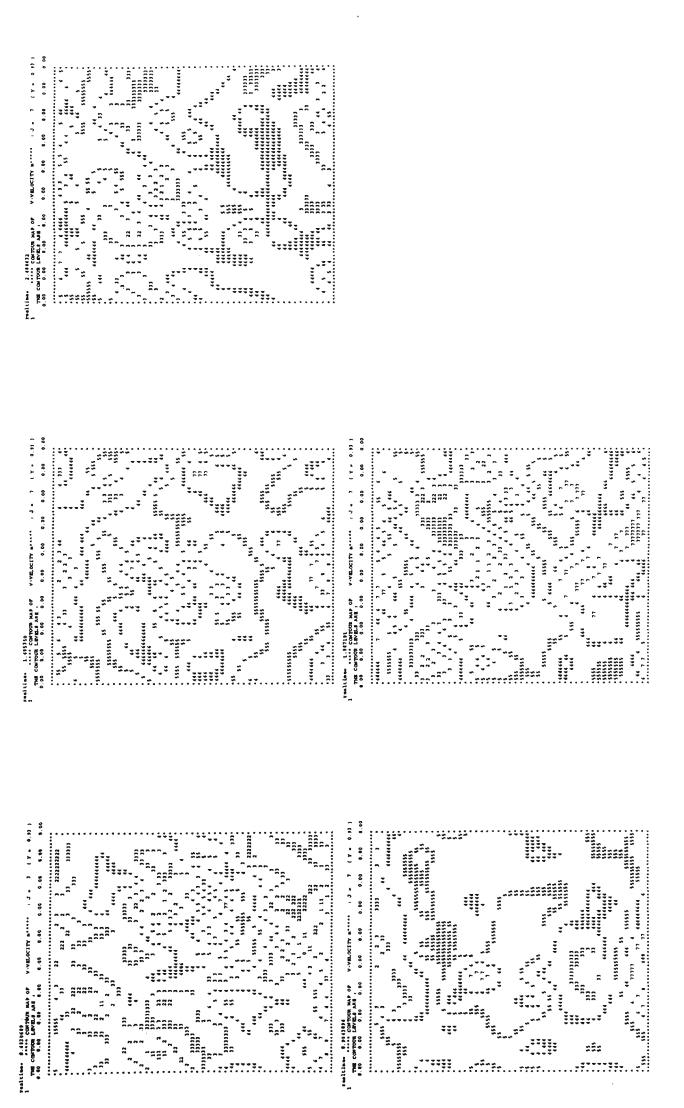


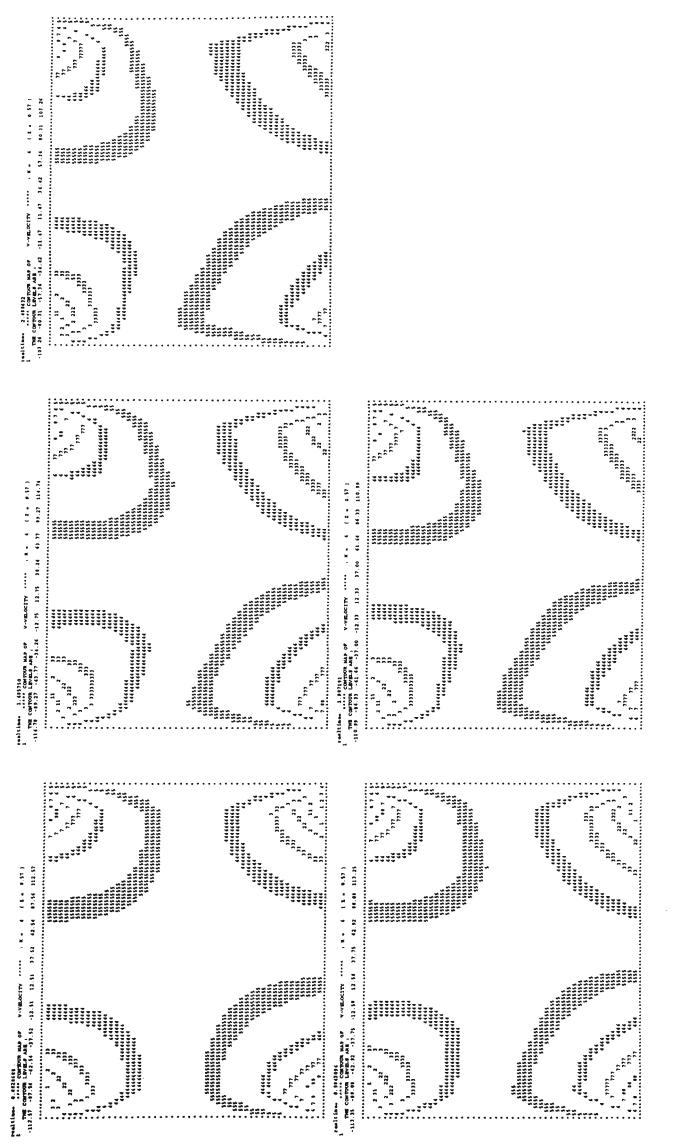








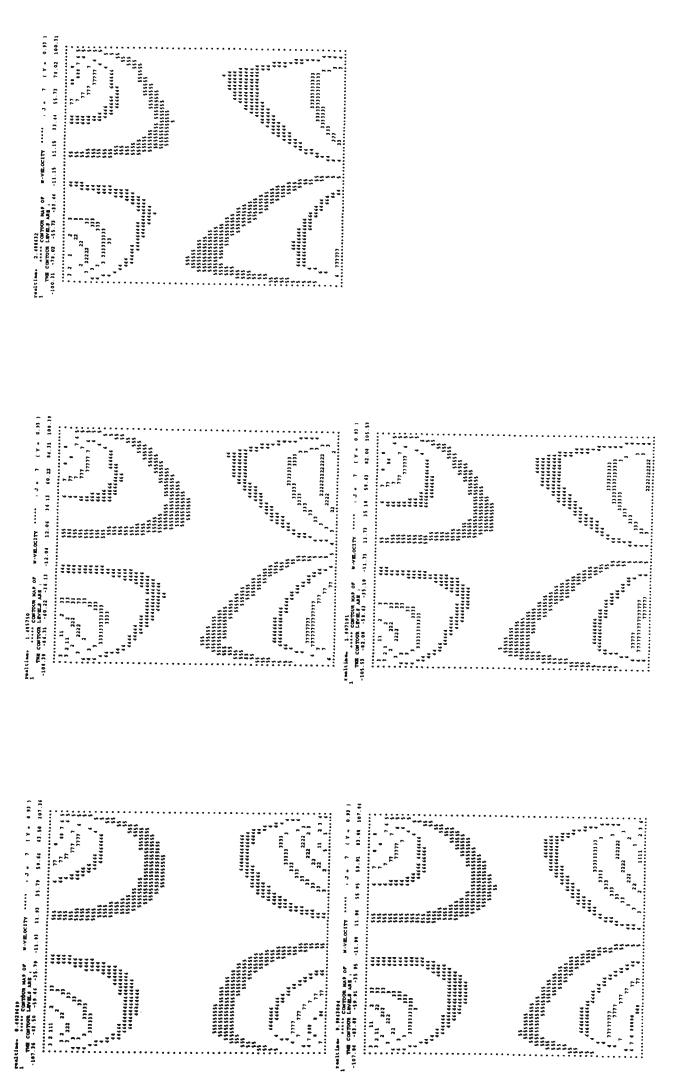


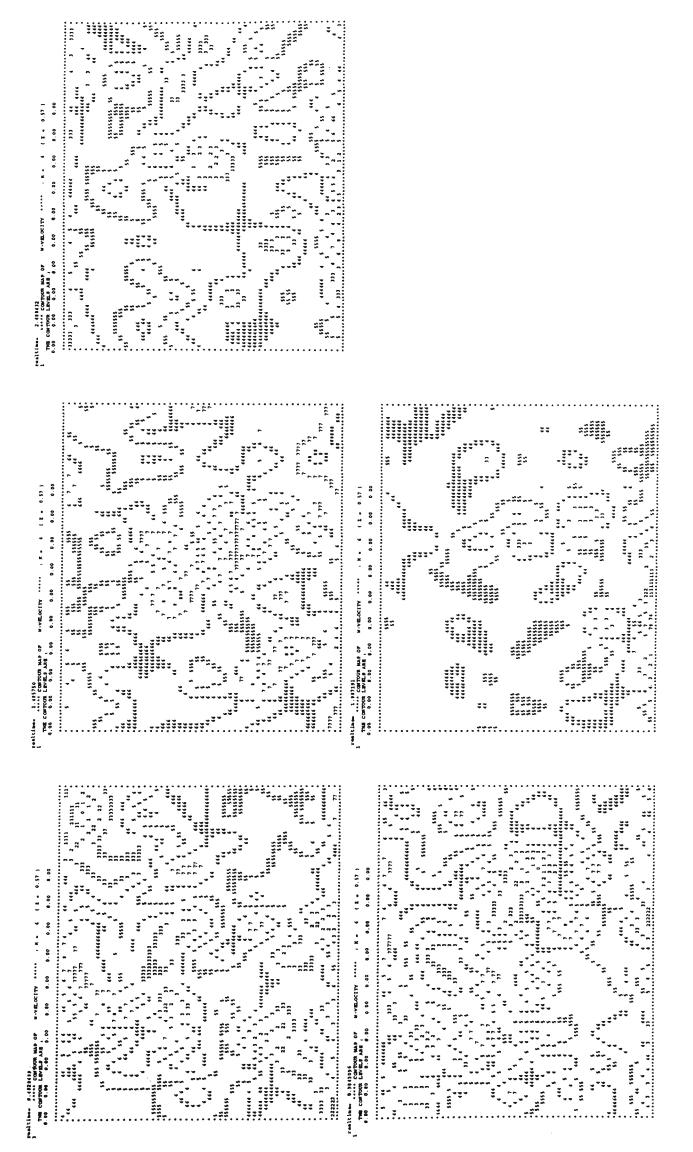


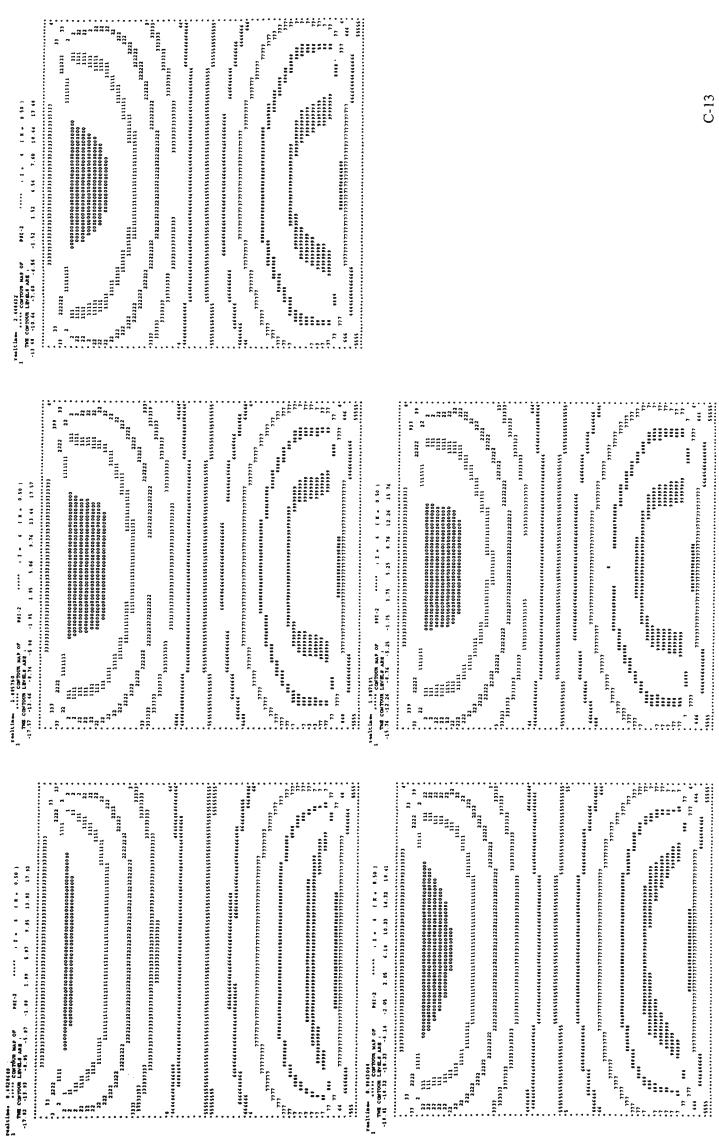
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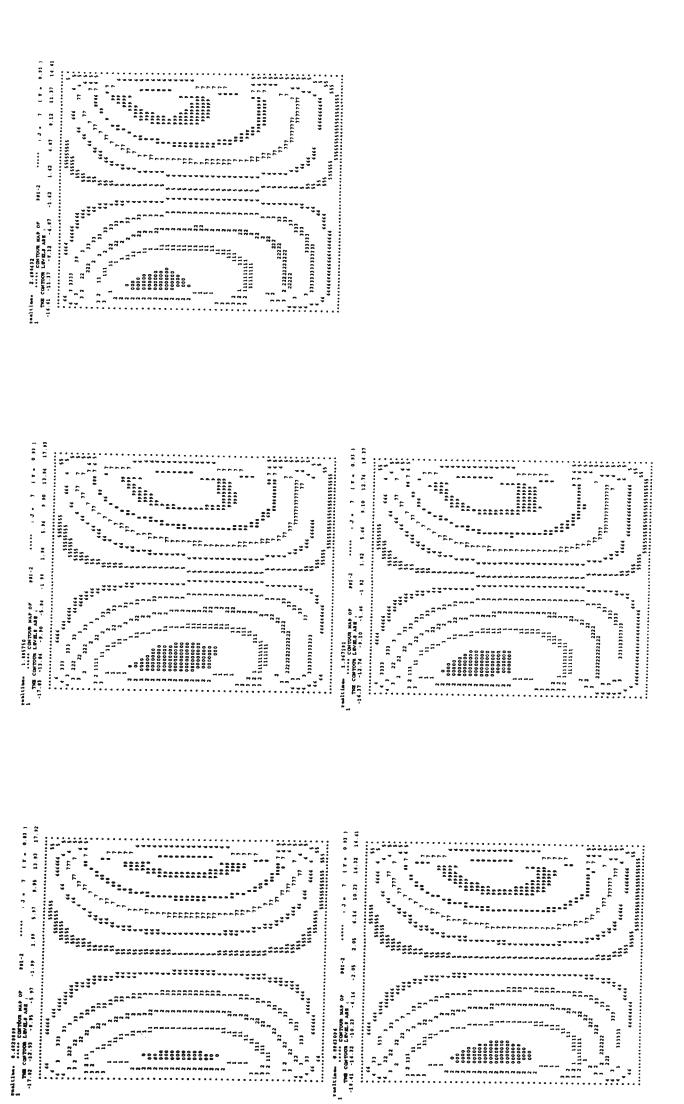
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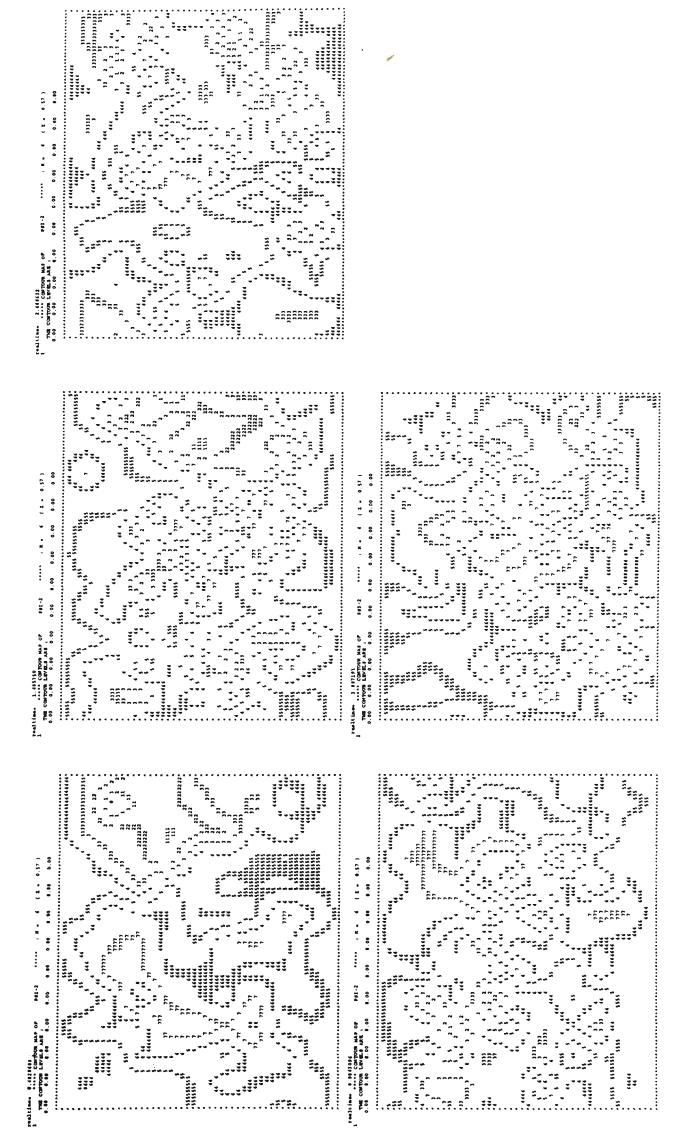
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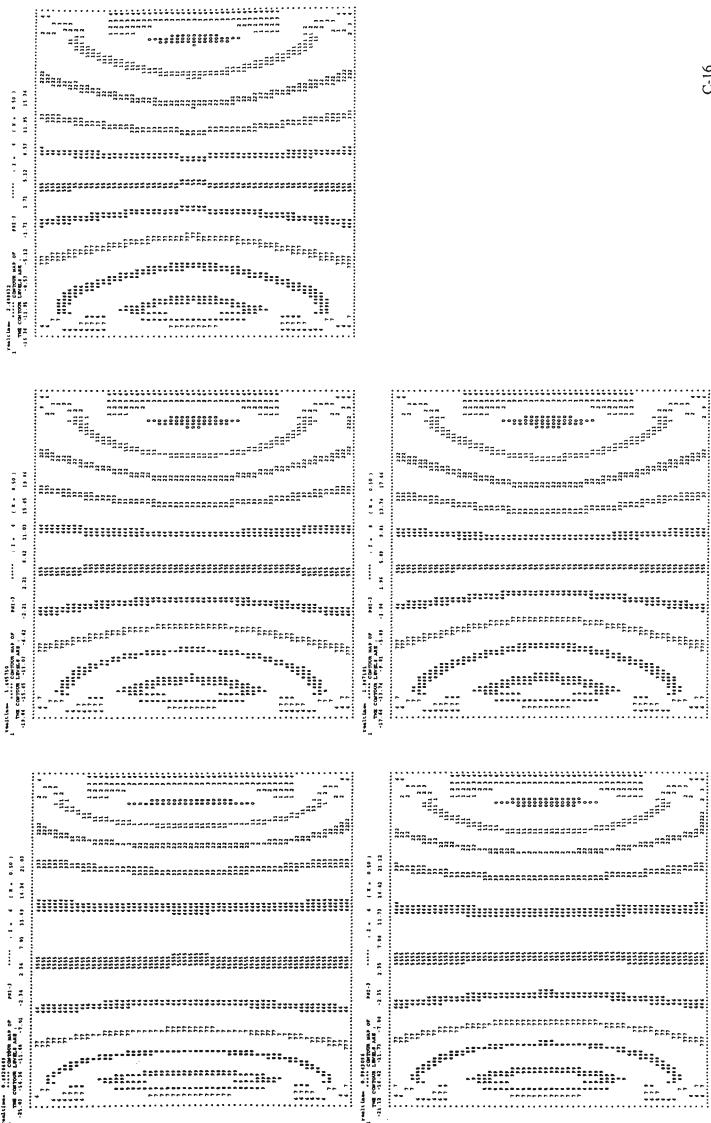


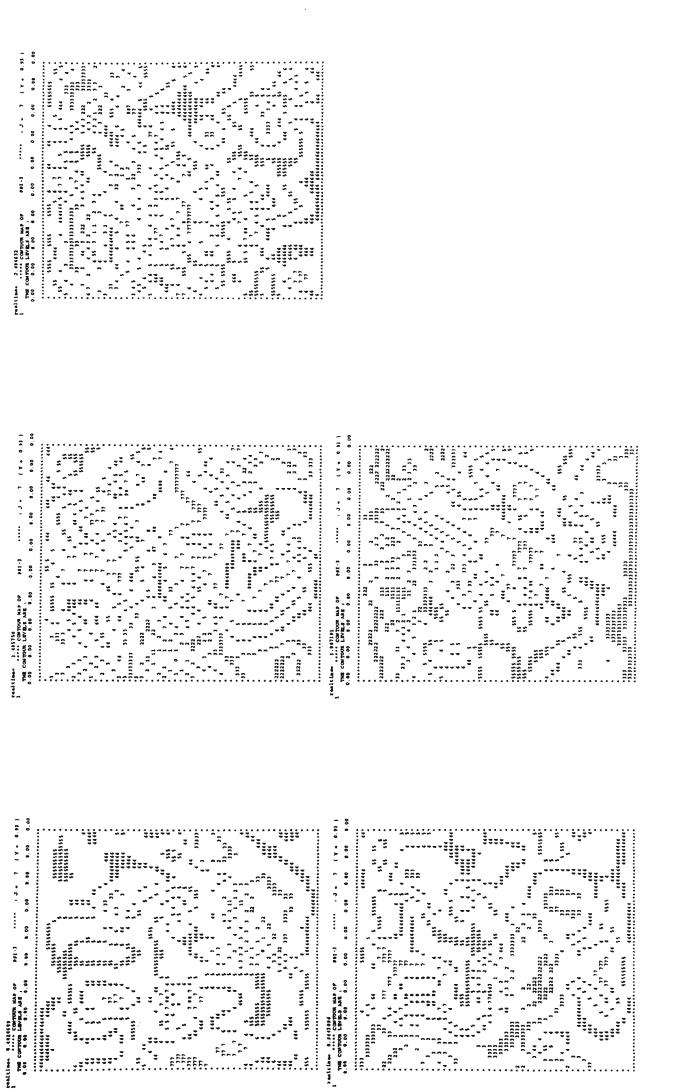


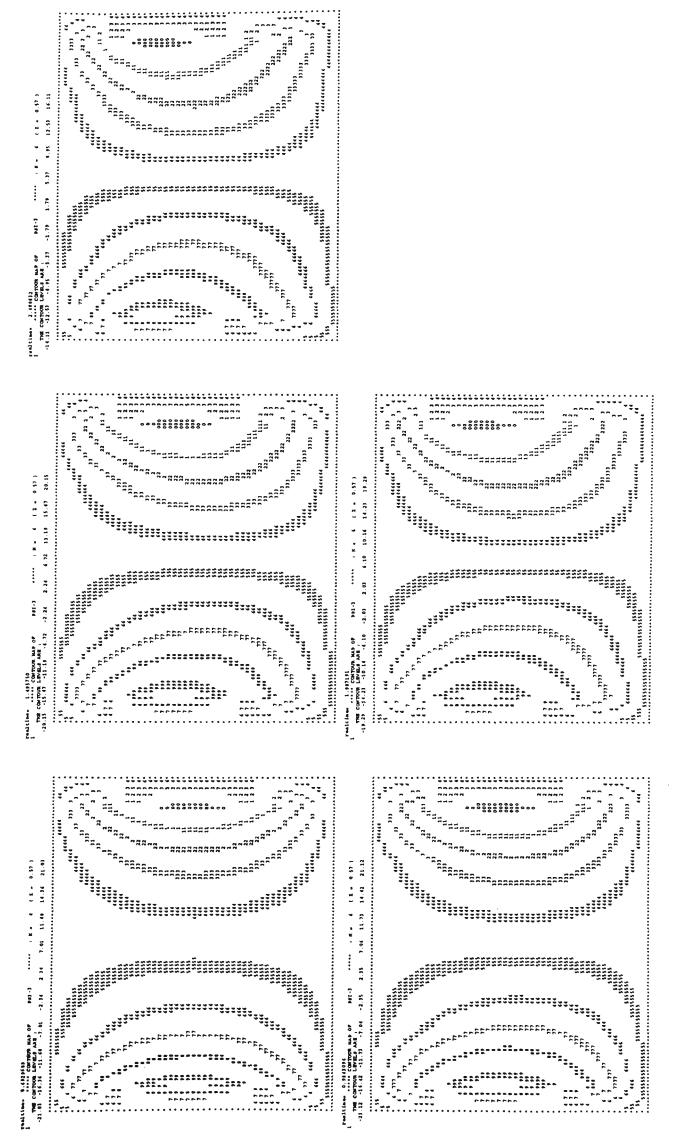












| APPENDIX D Program AGRI_3D.FOR and its input files | subroutine gfunctns(tpnt, afunc, ma) |
|--|--|
| Table of content | |
| program agri_3d.for | subroutine gsource(tpnt,q,npt,nbest,abest) |
| subroutine banner | |
| subroutine datin | |
| subroutine distb | subroutine resip2 |
| subroutine div(f1,f2,f3,head,divlog) | subroutine resip3 |
| subroutine drawcurv | subroutine resit |
| subroutine gaussjdn(a,n,np,b,m,mp) | subroutine search(pos,f,index,m) D-58 |
| function genran(ii,jj) | subroutine setcon |
| subroutine htc | subroutine simpsn(fun,nx,hx,answer) 0-63 |
| subroutine inital | subroutine sumary |
| subroutine interp | subroutine tbc |
| subroutine iterat | subroutine thomas(nn) D-65 |
| subroutine iterout(itheta) | subroutine tsolp |
| subroutine location | subroutine ttime(start,rung,runend) 0-67 |
| subroutine map | |
| subroutine mapt | subroutine veloc |
| subroutine maxmin(fv,head) | subroutine writer |
| subroutine maxval(fv,head) | Input file INPARAM |
| subroutine mprtx(f,head,ipos) | gridfile |
| subroutine mprty(f,head,jpos) | |
| subroutine mprtz(f,head,kpos) | |
| subroutine outfiles | |
| subroutine output | |
| subroutine plsolp | |
| subroutine p2solp | |
| subroutine p3solp | |
| | |

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L.P. Goh, E. Leonardi and G. de Vahl Davis, "Frecon3d - Programmers Manual. A Program for the Numerical Solution of Mixed Convection in a Three-Dimensional Rectangular Leonardi and G. de Vahl Davis, "Frecon3d Mech. and Ind. Engineering, Report 1988/fmt/8, (1988). Mech. and Ind. Engineering, Report 1988/fmt/7, (1988). *** job initiation and sequence control *** Cavity", The University of New South Wales, Mixed Convection in a Three-Dimensional Cavity", The University of New South Wales, Numerical /logc/reed,rite,strt,dist,heat,nuss,tran /fileno/inparam,irg,ireport,itin,itout parameter(nxmax=51,nymax=51,nzmax=51,max=51) reed, rite, strt, dist, heat, nuss, tran main program *** the /timestrg/timestrg,datestrg L.P. Goh, E. Leonardi and Users Manual. A Program for /vel/u(nxmax,nymax,nzmax), character timestrg*11,datestrg*9 /logr/rt,rp1,rp2,rp3,rmax /pl/pl(nxmax,nymax,nzmax) v(nxmax,nymax,nzmax), rt,rp1,rp2,rp3,rmax /logd/divv,divp,dmax start, runng, runend /exprmnt/exprmnt divv, divp, dmax /logi/blup,cgd character exprmnt*8 plup, cad Reference finish and/or logical logical ogical logical ogical ogical common common common common common common common common 0 0 0 0 0 0 0 0 0 0 0 0 ***************** Forward Time and Central (Non-Uniform) Spatial Differences New South Wales, for providing the author convective processes in three-dimentional Professor E. Leonardi, of University of Acknowledgements: The author is grateful to Associate with access to his model of natural Containing Agricultural Produce with a Three-Dimensional Rectangular Box Department of Mechanical Engineering, Vector Potential Formulation State Victoria University of Technology Respiring Heat Generation Footscray , Victoria, Australia. Transient Result and a Steady Result Will Be Obtained Convection Using in enclosures. R. Thorpe T. Lleonart Free Patrick X.P. Li . . . program agri_3d.for Supervisors: Address: Author:

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                                                                                                                                                                                                                                                                                                     ... write starting time onto file...
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                                                                                                                                                                                                                                       ... open output files
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'porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       'File names for output results are ',a8,'.*.')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ', f6.1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              2148 format(/, '(Effective) diameter of fruit or vegetabale=
                                             /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              is ', a8, /
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if ((srcetype.eq.'c').or.(srcetype.eq.'C')) then
                                                                                                                                                                                                /vmppos/rmx(nxmax),rmy(nymax),rmz(nzmax)
                                                                                                                                                                                                                                                                                                                                   /epsonnu/epson,xll,annu,gravity,ddd,keff
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /txty/tpnt(10),q(10),npt,nparam,srcetype
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   'Initial temperature of porous media =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(ireport,2147) xll*arx, xll*ary, xll*arz 2147 format(/,'Dimension of box(x*y*z)= ',f5.2,'m x
                                                                                                                                                                              'vmploc/mx(nxmax),my(nymax),mz(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             write(ireport,2154) tstrt*(thot-tcold)+tcold
                                                                                       hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                          , pstx2, psty2, pstz2, pstx3, psty3, pstz3, pstx4, pstx4, pstz4, pstz4, pstx5, pstx5, pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    format( /,'Respiration heating parameters:')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          ,pstx8,psty8,pstz8,pstx9,psty9,pstz9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ,pstx6,psty6,pstz6,pstx7,psty7,pstz7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          experiment
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(ireport,2166)(tpnt(i),i=1,npt)
format ('Temperature at: ',10(f5.1,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             : ', 10(f\bar{5}.1, 1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       format(//,a80,//,'Run number # = ',i4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport, 2021) exprmnt, exprmnt
                                                                 /h/hx(max),hy(max),hz(max),
                                                                                                                                                                                                                                                                                                           /ccaa/cc0,dtemp,tcold,thot
                                                                                                         /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                      /pstxyz/pstx1,psty1,pstz1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2167)(q(i),i=1,npt)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                format(/,'Temperature of cold wall
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  wall
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                                                                                                                                  /vmpfrm/xc,yc,zc,vpform
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zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb
/tbi/ixlyl,ixlyh,ixlzl,ixlzh,ixhyl,ixhyh,ixhzl,ixhzh,
iylxl,iylxh,iylzl,iylzh,iyhxl,iyhxh,iyhzl,iyhzh,
izlxl,izlxh,izlyl,izlyh,izhxl,izhxh,izhyl,izhyh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   /reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,
                                                                                                                                                                                                                                                                                                                                                                           character table(16,132)*1,mxlci*1,mxhci*1,mylci*1,myhci*1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /tbr/xlci,xlcg,xlca,xlcb,xhci,xhcg,xhca,xhcb,
                                                                 pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /logi/blup.cgd
/logc/reed,rite,strt,dist,heat,nuss,tran
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mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       /fileno/inparam,irg,ireport,itin,itout
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pstx4,psty4,pstz4,pstx5,psty5,pstz5
                                             pstx8,psty8,pstz8,pstx9,psty9,pstz9
                                                                                                                                reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /tapcom/rfile(94),ifile(67),lfile(10)
                       , pstx6, psty6, pstz6, pstx7, psty7, pstz7
                                                                                                                                                                                                    vxp1, vxp2, vxp3, vxt, vxu, vxv, vxw
                                                                                                                                                                                                                                             vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                         \mathtt{mxp1}, \mathtt{mxp2}, \mathtt{mxp3}, \mathtt{mxt}, \mathtt{mxu}, \mathtt{mxv},
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                                                                                                                                                                                                                                                                                       vzpl, vzp2, vzp3, vzt, vzu, vzv, vzw,
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /velbc/xlu,xlv,xlw,xhu,xhv,xhw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ylu,ylv,ylw,yhu,yhv,yhw,
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                                                                                                                                                      rt, rp1, rp2, rp3, rmax
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                                                                                                                            /, Diffusivity of porous medium
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format( 'Darcy number of y direction
format( 'Darcy number of z direction
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                                                                                                                                                                                                                                                         /,'Density of porous medium write(ireport,2161) keff
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           format('Unit for heating rate is
format('Unit for heating rate is
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ormat( 'Density of fluid
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                        ','{',a11,'}')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          2412 format(/,'Controls: reed rite strt dist heat nuss tran', + Residuals: rt rpl rp2 rp3 rmax ')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,2413) reed,rite,strt,dist,heat,nuss,tran,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ',1pg10.4,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              p (pdist)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(ireport,2322) vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                             + /24x,'Theta cct = ',1pg10.4,4x,'disturb. to
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 mxp1, mxp2, mxp3, mxt, mxu, mxv, mxw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 doo
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(ireport,2410) ccp,itercmpo,cct,pdist
                                                                                                                                                                                                                      step for t =',1pg10.4)
                                                                                                                                                                                                                                                                       format('Inner time step for p =',1pg10.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  4x, 'Max. no. of iterations = ',i6,
                      2210 format(//,'Mesh =',i3,' *',i3,' *',i3,'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             2410 format(/, 'Convergence limits on - psi
                                                                       write(ireport, 2220) alpp, altp, stabr
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       >
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2415 format('Divergence: divv divp dmax')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ×
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(ireport,2414) divv,divp,dmax
write(ireport,2210) nx,ny,nz,mesh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    rt,rp1,rp2,rp3,rmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           mv vm
                                                                                                                                                                                                                                                                                                                                              ... convergence limits and pdist
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        2413 format(9x,7(4x,11),11x,5(3x,11)) write(ireport,2415)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2320 format(//,5x,'Printing controls:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ٦
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         .. write printing controls ...
                                                                                                                                                                                             write(ireport,2221) dt*altp
                                                                                                                                                                                                                                          write(ireport, 2222) dt*alpp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 vp3 vt
                                                                                                                                                                                                                                                                                                                                                                                             write(ireport,2165) phierr
                                                                                                                                                                                                                                                                                                                                                                                                                      format('PHIERR = ', 1pg10.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ш
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           x planes:')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              2321 format(/,5x,' vpl vp2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     'mp1 mp2 mp3 mt
                                                                                                                                                                                                                          format('Main time
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(ireport,2412)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        write(ireport,2320)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,2321)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          2414 format(11x, 3(4x, 11))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2322 format(4x,14(3x,11))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,2324)
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... set boundaries of planes
                                                                                                                                                                                                                                                                                                                                             ... horizontal boundary
                                                                        .. vertical boundary
                                                                                                                                                                      <del>-</del> -
                                                                                                                                                                                                   -
                                                                                                                                                                                                                    -
             ,16x,'y--->')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            table(1,j) = '-'
table(16,j) = '-'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 70 j=114, 132
                                                                                                                                                                                                                                                                                                                                                                                                                                                                          table(16, j) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        IJ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               table(16, j) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 60 j=93,111
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       99
                                                                                                        do 10 i=2, 15
                                                                                                                                                                                                                                                                   table(i,111)
                                                                                                                                                                                                                                                                                                                                                                                         table(1,j)
table(16,j)
                                                                                                                                                                                                                                                                                                table(i,132)
                                                                                                                                                                                                                                                                                table(i,114)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  table(16, j)
                                                                                                                        table(i,3)
table(i,21)
                                                                                                                                                      table(i,24)
                                                                                                                                                                                                                    table(i,69)
table(i,87)
                                                                                                                                                                                                                                                                                                                                                                          do 20 j=3,21
                                                                                                                                                                      table(i,42)
                                                                                                                                                                                   table(i,48)
                                                                                                                                                                                                    table(i,66)
                                                                                                                                                                                                                                                   table(i,93)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        table(16, j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 30 j=24,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 40 j=48,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 do 50 j=69,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     table(1, j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  table(1, j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        table(1,j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          set axes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    table(1,j)
                                                                                                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              format(16x, 'z--->',16x, 'z--->',19x, 'z--->',16x, 'z--->',19x, 'y--->'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        + cb',/)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  2430 format(40x, 'Blank surface = adiabatic, heat flux or convective
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    2420 format(1h1,5x,'Thermal boundary conditions (note: contour ',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            2334 format(5x, 'Values and maps are printed for the following',
                                                                                                                                                                                                                         2344 format(5x,' Values and maps are printed for the following'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                2440 format(40x,' cg, ca & cb in the equation :cg*dt/dn = ca*t
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   levels = isothermal eg "0" implies theta=0.0; '
'"1" implies 0.0<theta<=0.11; etc')</pre>
                                                                                                                                                                                                                                                                                                                              = constant planes')
                                                                     = constant planes')
                                                                                                        write(ireport,2332) vzpl,vzp2,vzp3,vzt,vzu,vzv,vzw,
write(ireport,2325) ( mx(nplane), nplane=1,npx
2325 format( (3x,21(2x,i3)) )
                                                                                                                                                                                                                                                      write(ireport,2345) ( my(nplane), nplane=1,npy)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport, 2335) (mz(nplane), nplane=1,npz
                                                                                                                                                              myp1, myp2, myp3, myt, myu, myv, myw
                                                                                                                                                                                                                                                                                                                                                                                                                                   mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  'depending on the constants')
                                                                                                                                                                                                                                                                                                                            2
                                                                                                                                                                                                                                                                                                                                                                  vu
mw
                                                                                                                                                                                                                                                                                                                   2330 format(//,5x,'Printing controls:
                                                          2340 format(//,5x,'Prting controls:
                                                                                                                                                                                                                                                                                                                                                                                      mu mv
                                                                                                                                                                                                                                                                                                                                                                      vp3 vt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          format((3x,21(2x,i3)))
                                                                                                                                                                                                                                         'y planes:')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             ' z planes:')
                                                                                                                                                                                                                                                                       2345 format ( (3x,21(2x,i3))
                                                                                                                                                                                                                                                                                                                                                                 2331 format(/,5x,' vpl vp2 + 'mpl mp2 mp3 mt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    table(i,j) = '
                                               write(ireport,2340)
                                                                                            write(ireport,2341)
                                                                                                                                                                          2342 format(4x,14(3x,11))
                                                                                                                                                                                                          write(ireport,2344)
                                                                                                                                                                                                                                                                                                                                                     write(ireport,2331)
                                                                                                                                                                                                                                                                                                         write(ireport,2330)
                                                                                                                                                                                                                                                                                                                                                                                                                                             2332 format(4x,14(3x,11))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2420)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport,2334)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write (ireport, 2430)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 write(ireport,2440)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2460)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 5 i=1, 16
do 5 j=1, 132
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          2335
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         S
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if (xlci.le.0.88) then
mxlci = '8'
                                                                                                                                                                                                                                                                                                                                                                                                                                              if (xhci.le.0.88) then mxhci = '8'
                                                                                                                                                                                                                                                                                                                                                                                                     if (xhci.le.0.77) then
mxhci = '7'
                                                                                                                                                                                                                                                                                                                                                             if (xhci.le.0.66) then mxhci ≈ '6'
                                                                                                                                                                                                                                                                                                                   if (xhci.le.0.55) then
mxhci = '5'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       if (ylci.le.0.55) then
mylci = '5'
                                                                                                                                                                                                                                                                          if (xhci.le.0.44) then mxhci = '4'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (ylci.le.0.44) then
                                                                                                                                                                                                                                  if (xhci.le.0.33) then
mxhci = '3'
                                                                 mxlci = '9'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       if (ylci.le.0.33) then
mylci = '3'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      mxhci = '9'
                                                                                                                                                                                        if (xhci.le.0.22) then mxhci = '2'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if (ylci.le.0.22) then
mylci = '2'
                                                                                                                                                  if (xhci.le.0.11) then
mxhci = '1'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if (ylci.le.0.11) then
mylci = '1'
                                                                                                        if (xhci.eq.0.0) then
mxhci = '0'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (ylci.eq.0.0) then
mylci = '0'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             mylci = '4'
                                                      else
                                                                                                                                                                                                                                                                                                                                                                                          else
                                                                                                                                                                                                                                                                                                                                                  else
                                                                                                                                                                                                                                                                 else
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    else
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                                                                               endi f
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mxlci = '7'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if (xlci.le.0.66) then
                                                                                                                                                                                                                                                                                                                                                                                                                        ... set isothermal contour levels ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if (xlci.le.0.55) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if (xlci.le.0.44) then
mxlci = '4'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (xlci.le.0.33) then mxlci = '3'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    mxlci = '6'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if (xlci.le.0.22) then mxlci = '2'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          mxlci = '5'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (xlci.le.0.11) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (xlci.eq.0.0) then
mxlci = '0'
                                                                                                                                                                                                                                                                                                                                                  table(14,113) = '|'
table(13,113) = 'x'
table(15,113) = '|'
table(16,113) = '|'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    else
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       mxlci = '1'
                                                                                                                                                                                                           table (14,68)
table (13,68)
table (15,68)
table (16,68)
                                                                                                                                                                                                                                                                               table(14,92)
table(13,92)
table(15,92)
table(16,92)
table(14,2)
table(13,2)
table(15,2)
table(16,2)
                                                                     table(14,23)
table(13,23)
table(15,23)
table(16,23)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         else
                                                                                                                                          table(14,47)
                                                                                                                                                     table(13,47)
table(15,47)
                                                                                                                                                                                  table (16,47)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                               else
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0 0 0

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if (zlci.le.0.88) then mzlci = '8'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if (zhci.le.0.88) then
mzhci = '8'
                                                                                                                               if (zlci.le.0.77) then
mzlci = '7'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                mixlyl = int((real(ixlyl)/real(ny))*14.0)
mixlyh = int((real(ixlyh)/real(ny))*14.0)
mixlzl = int((real(ixlzl)/real(nz))*17.0)
mixlzh = int((real(ixlzl)/real(nz))*17.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        if (zhci.le.0.77) then mzhci = '7'
                                                                                    if (zlci.le.0.66) then mzlci = '6'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (zhci.le.0.66) then mzhci = '6'
                                         if (zlci.1e.0.55) then mzlci = '5'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if (zhci.le.0.55) then mzhci = '5'
                                                                                                                                                                                                                                                                                                                                                                                                               else
if (zhci.le.0.44) then
mzhci = '4'
                                                                                                                                                                                                                                                                                                                                                                                 if (zhci.le.0.33) then mzhci = '3'
                                                                                                                                                                                                                  mzlci = '9'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             mzhci = '9'
                                                                                                                                                                                                                                                                                                                                         if (zhci.le.0.22) then mzhci = '2'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      if (mixlyl.eq.0) mixlyl = 1
if (mixlzl.eq.0) mixlzl = 1
                                                                                                                                                                                                                                                                                                 if (zhci.le.0.11) then
mzhci = '1'
                mzlci = '4'
                                                                                                                                                                                                                                                      if (zhci.eq.0.0) then mzhci = '0'
                                                                                                                                                                                                    else
                                                                                                                                                           else
                                                                                                                    else
                                                                                                                                                                                                                            endi f
                                                                                                                                                                                                                                                                                     else
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                                                                                   if (ylci.le.0.88) then
mylci = '8'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (yhci.le.0.88) then
myhci = '8'
                                          if (ylci.le.0.77) then
mylci = '7'
                                                                                                                                                                                                                                                                                                                                                                                                                                                if (yhci.le.0.77) then
myhci = '7'
else
if (ylci.le.0.66) then
mylci = '6'
                                                                                                                                                                                                                                                                                                                                                                                                                           if (yhci.le.0.66) then myhci = '6'
                                                                                                                                                                                                                                                                                                                                                                                  if (yhci.le.0.55) then myhci = '5'
                                                                                                                                                                                                                                                                                                                                         if (yhci.le.0.44) then myhci = '4'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if (zlci.le.0.44) then
                                                                                                                                                                                                                                                                                                if (yhci.le.0.33) then myhci = '3'
                                                                                                                              mylci = '9'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (zlci.le.0.33) then
mzlci = '3'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         myhci = '9'
                                                                                                                                                                                                                                                    if (yhci.le.0.22) then myhci = '2'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (zlci.le.0.22) then mzlci = '2'
                                                                                                                                                                                                           if (yhci.le.0.11) then
myhci = '1'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (zlci.le.0.11) then
mzlci = '1'
                                                                                                                                                                  if (yhci.eq.0.0) then
myhci = '0'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              if (zlci.eq.0.0) then
mzlci = '0'
                              else
                                                                                                                else
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           else
```

endi f

else

endi f

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y-z plane; x=',f5.2,
x-z plane; y=',f5.2,
x-y plane; z=',f5.2,/)
                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2470) (table(i,j), j=1, 132)
         mizlyh = int((real(izlyh)/real(ny))*17.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         xhcb,
                                                                                                                                                                                               int((real(izhx1)/real(nx))*14.0)
int((real(izhxh)/real(nx))*14.0)
int((real(izhy1)/real(ny))*17.0)
int((real(izhyh)/real(ny))*17.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,2490) xlca, xlcb, xhca,
                                                                                                                                                                                                                                                                                                                                                    do 130 j=mizhyl+114, mizhyh+114
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       yhcb,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            zlca, zlcb, zhca, zhcb
                                                                                                                 do 120 j=mizlyl+93, mizlyh+93
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     2490 format(2x,'ca=',f5.2,1x,'cb=',f5.2,

4x,'ca=',f5.2,1x,'cb=',f5.2,

7x,'ca=',f5.2,1x,'cb=',f5.2,

4x,'ca=',f5.2,1x,'cb=',f5.2,

7x,'ca=',f5.2,1x,'cb=',f5.2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,2480) arx, ary, arz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ',5x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     , 5x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          , 5x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ylca, ylcb, yhca,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(ireport,2485) xlcg, xhcg,
                                                                                  if (izl) then
do 120 i=mizlxl+1, mizlxh+1
                                                                                                                                                                                                                                                                                                                                     do 130 i=mizhx1+1, mizhxh+1
                                                                                                                                   table(i,j) = mzlci
                                                                                                                                                                                                                                                                                                                                                                        table(i,j) = mzhci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2480 format(/2x,'y-z plane; x=0.0-

6x,'x-z plane; y=0.0+

6x,'x-y plane; z=0.0+
                                                                                                                                                                                                                                                                                  п
                                             mizlxl
                                                           mizlyl
                                                                                                                                                                                                                                                                               mizhxl
mizhyl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            yhcg,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               2485 format (2x,'cg=',f5.2,1x,'

4x,'cg=',f5.2,1x,'

7x,'cg=',f5.2,1x,'

4x,'cg=',f5.2,1x,'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      zlcg, zhcg
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                7x, 'cg=', f5.2,1x,'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               4x, 'cg=', f5.2, 1x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ylcg,
                                     if (mizlx1.eq.0)
if (mizly1.eq.0)
                                                                                                                                                                                                                                                                         (mizhxl.eq.0)
                                                                                                                                                                                                                                                                                          (mizhyl.eq.0)
                                                                                                                                                                                                                                                                                                                                                                                                                               do 140 i=1, 16
                                                                                                                                                                                                                                                                                                                     if (izh) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                             2470 format(132ai)
                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                  ij
                                                                                                                                                                                                                                 H
                                                                                                                                                                                                              mizhxh
                                                                                                                                                                                                                                              mizhyh
                                                                                                                                                                                                 mizhxl
                                                                                                                                                                                                                               mizhyl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            140 continue
                                                                                                                                                                  endif
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                U
                                                                                                                           = int((real(ixhzl)/real(nz))*17.0)
= int((real(ixhzh)/real(nz))*17.0)
                                                                                                               = int((real(ixhyh)/real(ny))*14.0)
                                                                                                int((real(ixhyl)/real(ny))*14.0)
                                                                                                                                                                                                                                                                                                                                                = int((real(iylxh)/real(nx))*14.0)
= int((real(iylzl)/real(nz))*17.0)
= int((real(iylzh)/real(nz))*17.0)
                                                                                                                                                                                                                                                                                                                                   int((real(iylxl)/real(nx))*14.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    = int((real(iyhxh)/real(nx))*14.0)
= int((real(iyhzl)/real(nz))*17.0)
= int((real(iyhzh)/real(nz))*17.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       = int((real(iyhxl)/real(nx))*14.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          = int((real(izlx1)/real(nx))*14.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        int((real(izlxh)/real(nx))*14.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        int((real(izlyl)/real(ny))*17.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 100 i=miylx1+1, miylxh+1
do 100 k=miylz1+48, miylzh+48
                                                                                                                                                                                                                                       90 j=mixhyl+1, mixhyh+1
do 90 k=mixhzl+24, mixhzh+24
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 110 i=miyhx1+1, miyhxh+1
do 110 k=miyhz1+69, miyhzh+69
table(i,k) = myhci
do 80 j=mixly1+1, mixlyh+1
  do 80 k=mixlz1+3, mixlzh+3
                                     table(j,k) = mxlci
                                                                                                                                                                                                                                                                        table(j,k) = mxhci
                                                                                                                                                                                                                                                                                                                                                                                                                      " "
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           table(i,k) = mylci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         H - H
                                                                                                                                                                         if (mixhyl.eq.0) mixhyl
if (mixhzl.eq.0) mixhzl
                                                                                                                                                                                                                                                                                                                                                                                                                    miylxl
                                                                                                                                                                                                                                                                                                                                                                                                                              (miylzl.eq.0) miylzl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  miyhzl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       miyhxl
                                                                                                                                                                                                                                                                                                                                                                                                                (miylxl.eq.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (miyhxl.eq.0)
if (miyhzl.eq.0)
                                                                                                                                                                                                                        if (ixh) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                          if (iyl) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (iyh) then
                                                  continue
                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                    R
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                                                                                                                mixhyh
                                                                                                                                             mixhzh
                                                                                                mixhyl
                                                                                                                                 mixhzl
                                                                                                                                                                                                                                                                                                                                                   miylxh
                                                                                                                                                                                                                                                                                                                                                                               miylzh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   miyhzh
                                                                                                                                                                                                                                                                                                                                   miylxl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      miyhxh
                                                                                                                                                                                                                                                                                                                                                                  miylzl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       miyhx1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      miyhzl
                                                                                                                                                                                                                                                                                                       endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         mizlxh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           mizlxl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         mizlyl
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i f
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110

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if (ix1) then

80

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90

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format(1h1,25x,'** Mesh distribution for the three axes **',/)
     2530 format(2x,'l',4x,'w =',f5.2,5x,'l',2x,'l',5x,'w =',f5.2,4x,'l',
+ 5x,'l',5x,'w =',f5.2,4x,'l',2x,'l',5x,'w =',f5.2,4x,'l',
+ 5x,'l',5x,'w = na ',4x,'l',2x,'l',5x,'w = na ',4x,'l')
                                                                                                                                                                y-z plane; x=',f5.2,
x-z plane; y=',f5.2,
x-y plane; z=',f5.2,///)
                                                                                                                                                                                                                                                                       if( (meshtp.eq.'n') .or. (meshtp.eq.'t') .or. (meshtp.eq.'T') .or. tran )then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             i=isrt11,istp11
                                                                                             write(ireport,2470) (table(i,j), j=1, 132)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               format(/,' i = ',11(1x,i4,1x,5x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        if(iblk11 .eq. kount) istpl1=nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ' hx = ', 1x, 10(5x, f6.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if(iblk11*11 .ne. nx) iblk11=iblk11+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             jblk11=ny/11.
if(jblk11*11 .ne. ny) jblk11=jblk11+1
                                                                                                                                                 write(ireport,2580) arx, ary,
                                                                                                                                                                                                                                       ... write mesh distribution ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2620) (
                                                                                                                                                                                   6x, 'x-z  plane; y=0.0
                                                                                                                                                                                                    6x,'x-y plane; z=0.0
                                                                                                                                                                2580 format(/2x,'y-z plane; x=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        isrt11 = (kount-1)*10+1
istp11 = isrt11+10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 jsrt11 = (kount-1)*10+1
                                                                                                                                                                                                                                                                                                                                                                                                                                   format(//,5x,' x-axis:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          format(//,5x,' y-axis:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           istp10 = isrt10 + 9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        600 kount=1,iblk11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 700 kount=1,jblk11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   jstp11 = jsrt11+10
                                                                                                                                                                                                                                                                                                                            write(ireport,2600)
                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,2610)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,2710)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         isrt10 = isrt11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       format(
                                                                           do 220 i=11, 16
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ib1k11=nx/11.
                                                                                                                                                                                                                                                                                                                                                                                  x-axis
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          .. y-axis
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                              220 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 မှ
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600
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                                                                                    format(16x,'z--->',16x,'z--->',19x,'z--->',16x,'z--->',19x,'y--->'
,16x,'y--->')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport,2520) xlv,xhv,zlv,zhv
2520 format(2x,''',4x,'v =',f5.2,5x,''',2x,''',5x,'v =',f5.2,4x,''',
+ 5x,''',5x,'v = na ',4x,''',2x,''',5x,'v = na ',4x,''',
+ 5x,''',5x,'v =',f5.2,4x,''',2x,''',5x,'v =',f5.2,4x,''')
                                                 2500 format(//,5x,'Velocity boundary conditions',/)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  132)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             write(ireport,2470) (table(i,j), j=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             write(ireport,2530) xlw,xhw,ylw,yhw
4x, 'ca=', f5.2,1x, 'cb=', f5.2)
                                                                                                                                                                                                                                                                   table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                      table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                            table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       table(ivert,ihoriz)
                                                                                                                                         ... blanck out inside boxes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 156 ihoriz=115, 131
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 155 ihoriz=94, 110
                                                                                                                                                                                                                                                                                                    do 152 ihoriz=25, 41
                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 154 ihoriz=70, 86
                                                                                                                                                                                                              x = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    z = constant planes
                                                                                                                                                                                                                                                                                                                                                                            y = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                         do 153 ihoriz=49,65
                                                                                                                                                                                                                                                do 151 ihoriz=4,
                                                                     write(ireport,2501)
                                 write(ireport,2500)
                                                                                                                                                                            do 159 ivert=2,15
                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 200 i=1, 6
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
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10x, 'Mesh' =',i3,' *',i3,' *',i3,' -',
'{',all,'}',
/26x,'Alpha theta = ',f8.4,10x,'Stability ratio = ',f8.4,
/26x,'dt = ',f8.4)
                                                                                                                                                                                                                                                                                 write(ireport,2930)
format(///,30x,'*** Old mesh distribution ***',/)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     heat tran',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ccb
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if(iblk11 eq. kount) istp11=ifile(2)
isrt10 = isrt11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          if(iblk11*11 .ne. ifile(2)) iblk11=iblk11+1
                                                                                                                                     write(ireport,2907) rfile(17),rfile(20)
                                                               write(ireport,2906) rfile(16),rfile(19)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2909) rfile(25),rfile(26)
            Aspect ratio in x = ',0pf10.3,
5x,'Beta_x (DEG) = ',0pf10.3)
                                                                             2906 format( 'Aspect ratio in y = ',0pf10.3, type + 5x,'Beta_y (DEG) = ',0pf10.3)
                                                                                                                                                    2907 format( 'Aspect ratio in z = ',0pf10.3', + 5x,'Beta_z (DEG) = ',0pf10.3)
                                                                                                                                                                                                             ... mesh details and transient factors
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             - Psi
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           = ', 1pg10.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             write(ireport,2910) (lfile(1),1=1,4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             2910 format(/, Logicals - Converged dist + /,15x,11,7x,11,3(5x,11))
                                                                                                                                                                                                                                                                                                                                                                                                                                                    ... convergence limits and pdist
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      2909 format(/,'Convergence limits on + /,26x,'Theta cct = ',1
       2905 format( /'Aspect ratio in x =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ... write mesh distribution ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                isrt11 = (kount-1)*10+1
istp11 = isrt11+10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               900 kount=1,iblk11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       stp10 = isrt10 + 9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2931)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          iblk11=ifile(2)/11.
                                                                                                                                                                                                                                                 mesh=' See below
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   .. x-axis
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        format(/)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ф
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              C
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport, 2821) ( z(k), k=ksrt11,kstp11 )
format( 'z = ',11( f6.3 ,5x) )
write(ireport, 2822) ( hz(k), k=ksrt10,kstp10 )
format( 'hz = ',1x,10(5x,f6.3 ) )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      , k=ksrt11,kstp11 )
                                                                       2903 format(/,'Cumulative cpu. time in seconds for last + 'run no. is = ',f9.2,' seconds')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  2902 format(/'Cumulative number of iterations for last
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             : ',',a80,//' Run no.: ',i4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,2820) ( k , k=ksrt
format(/,' k = ',11(1x,i4,1x,5x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,*) 'Information of last run:'
if(jblk11 .eq. kount) jstp11=ny
jsrt10 = jsrt11
jstp10 = jsrt10+9
                                                                                                                                                                                                                                                                                                                                                                                                                           if(kblk11 .eq. kount) kstp11=nz
ksrt10 = ksrt11
                                                                                                                                                                                                                                                                                                                                if(kblk11*11 .ne. nz) kblk11=kblk11+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2905) rfile(15),rfile(18)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(ireport,2901) otitle,ifile(1) format(/,'Old title : ',/,a80,//'Ru
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ... non-dimensional parameters ...
                                                                       write(ireport,2720) (
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,2902) ifile(10)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2903) rfile(28)
                                                                                                                                                                                                                                                                                                                                                                                     ksrt11 = (kount-1)*10+1
kstp11 = ksrt11+10
                                                                                                                                                                                                                                                                             format(//,5x,' z-axis: ')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    'run no. is = ',i7)
                                                                                                                                                                                                                                                                                                                                                                     800 kount=1,kblk11
                                                                                                                                                                                                                                                                                                                                                                                                                                                              kstp10 = ksrt10+9
                                                                                                                                                                                                                                                         write(ireport,2810)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        write(ireport,*)
                                                                                                                                                                                                                                                                                                              kblk11=nz/11.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (reed) then
                                                                                                                                                                                                                       .. z-axis
                                                                                                                                                                                    continue
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= ',1pg10.4

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write(ireport,2981) ifile(44),ifile(45),ifile(48),ifile(49),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2982) ifile(46),ifile(47),ifile(50),ifile(51),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ifile(52),ifile(53),ifile(56),ifile(57),
ifile(60),ifile(61),ifile(64),ifile(65)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                2980 format(2x,'!',2x,'patch on = ',11,3x,
+ '!',2x,'!',3x,'patch on = ',11,2x,'!',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         5x,'!',2x,'i',3x,'patch on = ',11,2x,'!',
5x,'!',3x,'patch on = ',11,2x,
'!',2x,'!',3x,'patch on = ',11,2x,'!')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2981 format(2x,'!',4x,' j=',i2,',',i2,5x,' '',2x,'!',5x,' j=',i2,',',i2,4x,'!',5x,' i=',i2,',',i2,4x,'!',5x,' i=',i2,',',i2,4x,'!',5x,'!',5x,' i=',i2,',',i2,4x,'!',5x,'!',5x,'!',5x,'!',5x,'!',5x,'!',5x,'!',5x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'!',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,4x,'',i2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    '|',2x,'|',5x,' i=',i2,',',i2,4x,'|')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,2470) (table(i,j), j=1, 132)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(ireport,2980) lfile(5),lfile(6),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               5x,''',3x,'patch on = ',11,2x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          lfile(7),lfile(8),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           lfile(9), lfile(10)
                                                                                                                                            ij.
                                                                                                                               table(ivert,ihoriz)
                                                                                                                                                                                                 2 ihoriz=25, 41
table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                             table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 166 ihoriz=115, 131
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 165 ihoriz=94, 110
                                           x = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 164 ihoriz=70, 86
                                                                                                                                                                                                                                                                                                                         .. y = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    .. z = constant planes
                                                                                                                                                                                                                                                                                                                                                                            do 163 ihoriz=49,65
                                                                                                                                                                                         do 162 ihoriz=25,
                                                                                              do 161 ihoriz=4,
                                                                                                                                                           continue
                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 965 i=1, 5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  continue
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169
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              format(16x,'z--->',16x,'z--->',19x,'z--->',16x,'z--->',19x,'y--->'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,2945) ( hyold(j), j=jsrt10,jstp10 )
format( ' hy = ',1x,10(5x,f6.3 ) )
format(/,' i = ',11(1x,i4,1x,5x) )
write(ireport,2933) ( hxold(i), i=isrt10,istp10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               format(/,' k = ',11(1x,i4,1x,5x) )
write(ireport,2958) ( hzold(k), k=ksrt10,kstp10
format( ' hz = ',1x,10(5x,f6.3 ) )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            , j=jsrt11,jstp11 )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             , k=ksrt11,kstp11 )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2969)
format(lh1,5x,'Temperature boundary conditions',/)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if(jblk11 .eq. kount) jstp11=ifile(3)
jsrt10 = jsrt11
jstp10 = jsrt10+9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if(kblk11 .eq. kount) kstp11=ifile(4)
ksrt10 = ksrt11
kstp10 = ksrt10+9
                                                                                                                                                                                                                                                                             jblk11=ifile(3)/11.
if(jblk11*11 .ne. ifile(3)) jblk11=jblk11+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if(kblk11*11 .ne. ifile(4)) kblk11=kblk11+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              format(/,' j = ',11(1x,i4,1x,5x))
                                                                  hx = 1,1x,10(5x, f6.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2944) ( j
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2957) ( k
                                                                                                                                                                                                                                                                                                                                                                                                        jsrt11 = (kount-1)*10+1
jstp11 = jsrt11+10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              ksrt11 = (kount-1)*10+1
kstp11 = ksrt11+10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ... blanck out inside boxes
                                                                                                                                                                                                                                                                                                                                                                       do 910 kount=1,jblk11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                920 kount=1,kblk11
                                                                                                                                                                                                                     write(ireport,2931)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,2931)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    kblk11=ifile(4)/11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  write(ireport,2970)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ,16x,'y--->')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 169 ivert=2,15
                                                                    format(
                                                                                                                                                                ·· y-axis
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      .. z-axis
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
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, i=isrt11,istp11)

write(ireport,2932) (

2932

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format(2x, ||,,4x, 'v =',f5.2,5x,'|',2x,'|',5x,'v =',f5.2,4x,'|',5x,'v = na ',4x,'|',2x,'l',5x,'v = na ',4x,'|',5x,'v = na ',4x,'|',5x,'v =',f5.2,4x,'|',5x,'v =',f5.2,4x,'|')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             2994 format(2x,''',4x,'w =',f5.2,5x,'!',2x,'!',5x,'w =',f5.2,4x,'!'

5x,'!',5x,'w =',f5.2,4x,'!',2x,'!',5x,'w =',f5.2,4x,'!'

5x,'!',5x,'w = na ',4x,'!',2x,'!',5x,'w = na ',4x,'!'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2993) rfile(78),rfile(81),rfile(90),rfile(93)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(ireport,2992) rfile(83),rfile(86),rfile(89),rfile(92)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport,2994) rfile(79),rfile(82),rfile(85),rfile(88)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      y-z plane; x=',f5.2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2995) rfile(15),rfile(16),rfile(17)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,2470) (table(i,j), j=1, 132)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(ireport,2470) (table(i,j), j=1,
                                                                                                                                                                                                                      H
                                                                                                                                                                                                         table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                    do 172 ihoriz=25, 41
table(ivert,ihoriz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         table(ivert,ihoriz)
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 175 ihoriz=94, 110
                                                                                                   = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                            .. y = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     z = constant planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     2992 format(2x, '1', 4x, 'u = na
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 173 ihoriz=49,65
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 176 ihoriz=115,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 174 ihoriz=70,
                                                                                                                                                                    do 171 ihoriz=4,
                     do 179 ivert=2,15
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 978 i=11, 16
                                                                                                                                                                                                                                                     continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 977 i=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
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                                                                                                                                                                                                                                                                                                                                         write(ireport,2983) rfile(53),rfile(57),rfile(61),rfile(65),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2985) rfile(55),rfile(56),rfile(59),rfile(60),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   x-y plane; z=',f5.2,///)
ifile(54),ifile(55),ifile(58),ifile(59),
ifile(62),ifile(63),ifile(66),ifile(67)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       rfile(63),rfile(64),rfile(67),rfile(68),
rfile(71),rfile(72),rfile(75),rfile(76)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      y-z plane; x=',f5.2,
x-z plane; y=',f5.2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             write(ireport,2986) rfile(15),rfile(16),rfile(17)
                                                              2982 format(2x,'|',4x,' k=',i2,',',i2,5x,'
+ '|',2x,'|',5x,' k=',i2,',',i2,4x,'|',
+ '|',5x,' k=',i2,',',i2,4x,'|',
+ '|',2x,'|',5x,' k=',i2,',',i2,4x,'|',
+ ||',2x,'|',5x,' ||',i2,4x,'|',
+ ||',2x,'|',5x,' ||',i2,4x,'|',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       2990 format(//,5x,'Velocity boundary conditions',/)
                                                                                                                                                                                                                                                                                                                                                                                 rfile(69),rfile(73)
2983 format(2x,'l',4x,'theta=',f4.2,3x,
+ ''',2x,'l',5x,'theta=',f4.2,2x,'l',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           5x,'!',5x,'theta=',f4.2,2x,
'!',2x,'!',5x,'theta=',f4.2,2x,'!',
5x,'!',5x,'theta=',f4.2,2x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             '!',2x,'!',5x,'theta=',f4.2,2x,'!')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2470) (table(i,j), j=1, 132)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport, 2984) rfile(54), rfile(58)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               rfile(62),rfile(66),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         2985 format(2x,'ca=',f5.2,1x,'cb=',f5.2,+ 4x,'ca=',f5.2,1x,'cb=',f5.2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   7x, 'ca=',f5.2,lx, 'cb=',f5.2,
4x, 'ca=',f5.2,lx, 'cb=',f5.2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           7x, 'ca=',f5.2,1x, 'cb=',f5.2,4x, 'ca=',f5.2,1x, 'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.2,1x,'cb=',f5.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 rfile(70), rfile(74)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               6x, 'x-z plane; y=0.0
6x, 'x-y plane; z=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   2986 format(/2x,'y-z plane; x=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 blanck out inside boxes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                2984 format(2x,'cg=',f5.2,1x,'
+ 4x,'cg=',f5.2,1x,'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           7x, 'cg=', f5.2,1x,'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             4x, 'cg=', f5.2,1x,
7x, 'cg=', f5.2,1x,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2991)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          16x, 'y--->')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        write(ireport,2990)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 970 i=11, 16
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               970 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2991
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/reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,ccp,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                       character meshtp*1,exprmnt*8,gridfile*8,srcetype*1,datype*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /tbi/ixlyl,ixlyh,ixlzl,ixlzh,ixhyl,ixhyh,ixhzl,ixhzh,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          iylxl iylxh, iylzl, iylzh, iyhxl, iyhxh, iyhzl, iyhzh,
izlxl, izlxh, izlyl, izlyh, izhxl, izhxh, izhyl, izhyh
                                                     *** read in data (parameters and grid distribution)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /tbr/xlci,xlcg,xlca,xlcb,xhci,xhcg,xhca,xhcb,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ylci,ylcg,ylca,ylcb,yhci,yhcg,yhca,yhcb,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /logc/reed,rite,strt,dist,heat,nuss,tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /logpvm/vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                                                                       parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                mxp1,mxp2,mxp3,mxt,mxu,mxv,mxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          \texttt{myp1,myp2,myp3,myt,myu,myv,myw,}
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
mzp1, mzp2, mzp3, mzt, mzu, mzv, mzw
                                                                                                                                                                                        reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  , pstx2, psty2, pstz2, pstx3, psty3, pstz3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        .pstx4,psty4,pstz4,pstx5,psty5,pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            pstx6, psty6, pstz6, pstx7, psty7, pstz7
, pstx8, psty8, pstz8, pstx9, psty9, pstz9
                                                                                                                                                                                                                                                        vxp1, vxp2, vxp3, vxt, vxu, vxv, vxw
                                                                                                                                                                                                                                                                              mxp1,mxp2,mxp3,mxt,mxu,mxw,
                                                                                                                                                                                                                                                                                                                                            vzp1, vzp2, vzp3,vzt,vzu,vzv,vzw,
mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                  vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
                                                                                                                                                                                                                                                                                                                      myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /logtbc/ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                          xc*1,yc*1,zc*1,vpform*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      cct, tmax,pdist,rtime
                                                                                                                                                                                                                                                                                                                                                                                        ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /logr/rt,rp1,rp2,rp3,rmax
                                                                                                                                                                                                                                                                                                                                                                                                                               character title*80,otitle*80
                                                                                                                                                                                                          rt,rp1,rp2,rp3,rmax
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /title/title,otitle
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            integer pstx1,psty1,pstz1
                                                                                                                                                                                                                                    divv, divp, dmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /exprmnt/exprmnt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /alpfs/alpp,altp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /numcom/numit
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        drawstep
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          x-z plane; y=',f5.2,
x-y plane; z=',f5.2,///)
                                                                                                                                                                                                                                                                                hx(1) +hx(2) +hx(3) +hx(4),

hx(1) +hx(2) +hx(3) +hx(4),

hx(1) +hx(2) +hx(3) +hx(4) +hx(5),

hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6),

hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7),

hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7),

hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7) +hx(8),

hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7) +hx(8),
                                                                                                                                                                                                                                          vrite(iplt,8001) hx(1),hx(1),hx(2),hx(1),hx(2)+hx(3),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7),
hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7) +hx(8),
hx(1) +hx(2) +hx(3) +hx(4) +hx(5) +hx(6) +hx(7) +hx(8),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  nu_x_nx, nu_y_1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 write(45,*)'Central x-axis x_component_velocity-time
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(45,8001) hx(1), hx(1) + hx(2), hx(1) + hx(2) + hx(3),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           \tt pstx10, psty10, pstz10, pstx11, psty11, pstz11
                                                                                  write(iplt,*)'Central x-axis temperature_time
                                                                                                                                                                                                   'pstx6, psty6, pstz6, pstx7, psty7, pstz7, pstx8, pstx8, pstx9, pstx9, pstx9
                                                                                                                                                       , pstx2, psty2, pstz2, pstx3, psty3, pstz3
                                                                                                                                                                             ,pstx4,psty4,pstz4,pstx5,psty5,pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               'pstx6, psty6, pstz6, pstx7, psty7, pstz7
'pstx8, psty8, pstz8, pstx9, psty9, pstz9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ,pstx4,psty4,pstz4,pstx5,psty5,pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ,pstx2,psty2,pstz2,pstx3,psty3,pstz3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(inu,*)'Nusselt numbers: nu_x_1,
                                                                                                                                                                                                                                                                                                                                                                                                                       hx(1) + hx(2) + hx(3) + hx(4) + hx(5) + hx(6) +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                 hx(1) + hx(2) + hx(3) + hx(4) + hx(5) + hx(6) +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     hx(1)+hx(2)+hx(3)+hx(4)+hx(5),
hx(1)+hx(2)+hx(3)+hx(4)+hx(5)+hx(6),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 hx(1) + hx(2) + hx(3) + hx(4) + hx(5) + hx(6) +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           hx(1)+hx(2)+hx(3)+hx(4)+hx(5)+hx(6)+
                                                                                                                               write(iplt,8000) pstx1,psty1,pstz1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           format(16x,11(1x,i2,i2,i2))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(45,8000) pstx1,psty1,pstz1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       hx(7) + hx(8) + hx(9) + hx(10) + hx(11)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 hx(7) + hx(8) + hx(9) + hx(10) + hx(11)
6x,'x-z plane; y=0.0
6x,'x-y plane; z=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 format(16x,11(1x,f6.3))
                                                                                                                                                                                                                                                                                                                                                                                                                                           hx(7) + hx(8) + hx(9) + hx(10),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       hx(7) + hx(8) + hx(9) + hx(10),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               hx(1) + hx(2) + hx(3) + hx(4),
                                                                                                        transient results:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         transient results:'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         subroutine datin
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             write(inu,*)
                                          endif
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read maximum number of iterations and contour map output interval,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      format(//' solution halted, mesh size in input file greater',
                                                                                                                                                                                                                                                                               arz must be'
                                                                                                                                                                                                                     pe.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        greater',
                                                                                                                                                                                                                     arz must
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if ((nx.gt.nxmax).or.(ny.gt.nymax).or.(nz.gt.nzmax)) then
                                                                                                                                                      if ((arx.ne.1.0).and.(ary.ne.1.0).and.(arz.ne.1.0)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   pstx2, psty2, pstx2, pstx3, psty3, pstz3
read(inparam, 1036)  pstx4, psty4, pstz4, pstx5, pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            read(inparam,1036) pstx7,psty7,pstz7,pstx8,psty8,pstz8
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              format(//'solution halted, mesh size in input file
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   itercmpo, iterpp, mainiter, drawstep
                                                                                                                                                                                                                                                                             either arx or ary or
                                                                                                                                                                                                                     or
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   stabr, alpp, altp, phierr, ccp, cct
                                                                                                              read(inparam,1020) arx,ary,arz,betax,betay,betaz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  than maximum allowable in program !',//)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          ... read stabitily ratios, convergence criterion
                                                                                                                                                                                                                  either arx or ary
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ' than maximum allowable in program !'//)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          ... read positions for output transient results
                                                                                                                                                                                                                                                                                                                                                                                                                                                              пz
                               read(inparam,5555) tcold,thot,tstrt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                read(inparam,1036) pstx1,psty1,pstz1
                                                                                                                                                                                                                                                                                                                                                                                                                                                              ny,
                                                                        .. read box geometry parameters
                                                                                                                                                                                                                                                                                                                                                                                                                                                              nx,
                                                                                                                                                                                                                                                                          format(//' solution halted,
                                                                                                                                                                                                                format(//'solution halted,
                                                                                                                                                                                                                                  equal to 1.0 !', //)
                                                                                                                                                                                                                                                                                            ' equal to 1.0 !'//)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            format(/,9x,a1,1x,3(i5,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                   ... read nodal information
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           , pstx6,psty6,pstz6
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     pstx9,psty9,pstz9
                                                                                                                                                                            write(ireport,2010)
                                                                                                                                      format(/,6(g10.4,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,2020)
                                                                                                                                                                                                                                                                                                                                                                                                                                                         read(inparam,1026)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   read(inparam,1020)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                read(inparam,1035)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       format(/,4(i10,1x))
                                                                                                                                                                                                write(*,4010)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(*,4020)
                                                                                                                                                                                                                                                                                                                                                                            format(/,i10)
                                                                                                                                                                                                                                                                                                                                       stop
endif
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                                                                                                                                                                                                                                                                                                     /porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       /darcy/darcyx,darcyy,darcyz,darcy1,darcy2,darcy3
                                                                                  /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
/h/hx(max),hy(max),hz(max),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         read(inparam, 1020) keff, alphaf, cpfl, cpsd, rhof, rhos
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   ,file='inparam',status='old')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                                                                          /epsonnu/epson,xll,annu,gravity,ddd,keff
/ccaa/cc0,dtemp,tcold,thot
                                                                                                                                                                                                                        /vmppos/rmx(nxmax),rmy(nymax),rmz(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /txty/tpnt(10),q(10),npt,nparam,srcetype
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          read(inparam, 5555) epson, xll, annu, gravity, ddd
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                                                                                                                        hxold(max),hyold(max),hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                              pstx4, psty4, pstz4, pstx5, psty5, pstz5
,pstx6, psty6, pstz6, pstx7, psty7, pstz7
, pstx8, psty9, pstz9, pstz9
                                                                                                                                                                                                                                                                                                                                                                                                                             pstx2,psty2,pstz2,pstx3,psty3,pstz3
/velbc/xlu,xlv,xlw,xhu,xhv,xhw,
                       Ylu, Ylv, Ylw, Yhu, Yhv, Yhw,
                                           zlu,zlv,zlw,zhu,zhv,zhw
                                                                                                                                           /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                         /pstxyz/pstx1,psty1,pstz1
                                                                                                                                                              /vmpfrm/xc,yc,zc,vpform
                                                                                                                                                                                                                                                                                                                                                                                    'pst/pstx,psty,pstz
                                                                                                                                                                                                                                              /mapcom/mnx, mny, mnz
                                                                                                                                                                                    /vmpnum/npx,npy,npz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               'param_q/qparam(20)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /gridfile/gridfile
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 numshow/numshow
                                                                                                                                                                                                                                                                  'phierr/phierr
                                                                                                                                                                                                                                                                                                                                                                /draw/drawstep
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   'iterpp/iterpp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /datype/datype
                                                             /mesh/meshtp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               format(/,5(g13.4,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /tstrt/tstrt
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     open(unit=inparam
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                                                                                                                                                                                                                                                                                      /da/da
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   common
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read(inparam,1056) ylu, ylw, yhu, yhw
format(//,f5.2,lx,5x,1x,f5.2,1x,20x,f5.2,1x,5x,1x,f5.2)
                  format(///,5x,1x,2(f5.2,1x),20x,5x,1x,2(f5.2,1x))
                                                                                                                                                                                                                                                         vxp3, vxt, vxu,
                                                                                                                                                                                                                                                                                               mxn,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         vzn,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           mzu,
                                                                                                                                                                                                                                                                                         mxp3, mxt,
                                                                                       format(//,2(f5.2,1x),5x,1x,20x,2(f5.2,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        vzt,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             myt,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         mzt,
                                                                       read(inparam,1060) zlu, zlv, zhu, zhv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       my(i) = int(rmy(i)*(ny-1)/ary) +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          myp3,
                                                                                                                                                                                                                                                                                                                                                                       read(inparam,1075) (rmx(i),i=1,npx)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          vyp3,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     vzp3,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      mzp3,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    read(inparam,1075) (rmy(j),j=1,npy)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                read(inparam,1075) (rmz(k),k=1,npz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                             read(inparam,1080) (mx(i),i=1,npx)
                                                                                                                                                                                                                                                                                                                                                                                                                          mx(i) = int(rmx(i)*(nx-1)/arx)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         read(inparam,1080) (my(j),j=1,npy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     mz(i) = int(rmz(i)*(nz-1)/arz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      read(inparam,1080) (mz(k),k=1,npz)
                                                                                                                                                                                                                                                read(inparam,1065) vxp1, vxp2,
                                                                                                                                                                                                                                                                                  read(inparam,1065) mxp1, mxp2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                read(inparam,1065) myp1, myp2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       vyp1, vyp2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            read(inparam,1065) vzp1, vzp2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               read(inparam,1065) mzp1, mzp2,
                                                                                                                                                                                                               ... read printing controls ...
                                                                                                                                                                                                                                                                                                  read(inparam,1070) xc, npx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           yc, npy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              read(inparam,1070) zc, npz
                                                                                                                         ... read printing form ...
                                                                                                                                                                                                                                                                                                                                                                                      1075 format( (/,11(f5.2,1x)) )
                                                                                                                                                                                                                                                                                                                     format(/,4x,a1,37x,i5)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           1080 format( (/,11(i5,1x))
                                                                                                                                                                                                                                                                                                                                                      if (xc.eq.'c') then
                                                                                                                                                           read(inparam,1062)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if (yc.eq.'c') then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if (zc.eq.'c') then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 read(inparam,1065)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    read(inparam,1070)
                                                                                                                                                                            format(///,4x,al)
                                                                                                                                                                                                                                                                                                                                                                                                         do 50 i=1, npx
                                                                                                                                                                                                                                                                     format(/,7x,714)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 60 i=1, npy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 70 i=1, npz
                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                             else
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                  1055
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  pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     size of isothermal patch larger'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        patch larger'
                                                                                                                                                                                                                                                                                                                                                                                   ylcg,ylca,ylcb, yhcg,yhca,yhcb
ylcg,ylca,ylcb, yhcg,yhca,yhcb
1051) izl, zlci, izlxl,izlxh,izlyl,izlyh,
izh, zhci, izhxl,izhxh,izhyl,izhyh,
                                                                                                                                                                         read(inparam,1044) reed, rite, strt, dist, heat, nuss
                                                                                                                                                                                                                                                                                                                                                     read(inparam,1050) ixl, xlci, ixlyl,ixlyh,ixlzl,ixlzh,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  . or
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              zlcg,zlca,zlcb, zhcg,zhca,zhcb
11x,f5.2,4i4, 5x, 11,11x,f5.2,4i4,
                                                                                                                                                                                                                                                                                                                                                                      ixh, xhci, ixhyl,ixhyh,ixhzl,ixhzh,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            format(//,'solution halted, size of isothermal
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ( ixl.and.((ixlyh.gt.ny).or.(ixlzh.gt.nz))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ixh.and.((ixhyh.gt.ny).or.(ixhzh.gt.nz))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    5x, 11,11x,f5.2,
5x, 3(f5.2,1x)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       izh.and.((izhxh.gt.nx).or.(izhyh.gt.ny))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            than the size of the wall !',//)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    iyl.and.((iylxh.gt.nx).or.(iylzh.gt.nz))
iyh.and.((iyhxh.gt.nx).or.(iyhzh.gt.nz))
izl.and.((izlxh.gt.nx).or.(izlyh.gt.ny))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 solution halted, size of isothe than the size of the wall !'//)
                                                                                                                                                                                                                                                                                                                   .. read temperature boundary conditions
                                                                                                                                                                                                                                                               read(inparam,1047) mnx,mny,mnz,pdist
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         read(inparam,1055) xlv, xlw, xhv, xhw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ... read velocity boundary conditions
              format(/,3(i3,1x,i3,1x,i3,3x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 //,11,11x, f5.2,4i4,
                                                                                                                                                                                                                                                                                  format(/,3(i5,1x),42x,g10.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   //,3(f5.2,1x),15x,
                                                                                            norun
                                                                                                                                                                                                                               ... read map dimensions ...
                                                                                                                                         ... read input control
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  format(//' solution
                                                     ... read run number
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,2030)
read(inparam,1036)
                                                                                     read(inparam, 1010)
                                                                                                                                                                                            format(/,6(15,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(*,4030)
                                                                                                     format(/,i5)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             1051 format(
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      stop
endif
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              1036
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f(.not.((meshtp.eq.'b').or.(meshtp.eq.'B'))) then
                                                                                                                                                                                                                                                                                                           if((meshtp.eq.'t').or.(meshtp.eq.'T')) tran=.true.
                                                         else if((meshtp.ne.'b').or.(meshtp.ne.'B')) then
                                                                                                                                                                                                                                                                                                                                           .. normalise stepsizes in accordance to lengths
                                                                                           ... set uniform intervals between nodes
          read(irg,1028) (hz(k),k=1,nz-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                             sumhx = sumhx + hx(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          sumhy = sumhy + hy(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          sumhz = sumhz + hz(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            = hx(i)*ratiox
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         hy(j) = hy(j)*ratioy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          = hz(k)*ratioz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ratiox = arx/sumhx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ratioy = ary/sumhy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ratioz = arz/sumhz
                                                                                                                                                                                                                                                                                                                                                           boundaries ...
                                                                                                                                                                                                                                                                                                                                                                                                           sumhx = 0.0
do 20 i=1, nx-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 21 i=1, nx-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 30 j=1, ny-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 31 j=1, ny-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 40 k=1, nz-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 41 k=1, nz-1
                                                                                                                                         hx(i) = 1.0
                                                                                                                                                                                                                                             1.0
                                                                                                                                                                               'n
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        close(inparam)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          sumhy = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       sumhz = 0.0
                                                                                                                                                                                          hy (j) =
                                                                                                                                                                                                                                             hz (k) =
                                                                                                                       do 10 i=1,
                                                                                                                                                                                                             continue
do 12 k=1,
                            close(irg)
                                                                                                                                                                          do 11 \ j=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           hx(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
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                                                                                                                                                              continue
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                                                                                                                                                                                                                                                                                                                             read(inparam, 5555) tpnt(1), tpnt(2), tpnt(3), tpnt(4), tpnt(5)
read(inparam, 5555) tpnt(6), tpnt(7), tpnt(8), tpnt(9), tpnt(10)
read(inparam, 5555) q(1), q(2), q(3), q(4), q(5)
read(inparam, 5555) q(6), q(7), q(8), q(9), q(10)
                                                                                                                                                                               ... read in experiment name for creating output files ...
                                                                                               ... read in controls for calculation of divergence ...
             ... read in controls for calculation of residuals
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ... read Darcy numbers in x, y, and z directions
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if( (meshtp.eq.'n') .or. (meshtp.eq.'N')
+ .or. (meshtp.eq.'T') .or. (meshtp.eq.'t') ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               read(inparam,1008) darcyx,darcyy,darcyz,datype
format(/,g10.4,1x,g10.4,1x,g10.4,5x,a1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ,file=gridfile ,status='old')
                                            read(inparam,1085) rt, rp1, rp2, rp3, rmax
                                                                                                                                                                                                                                                                                                     npt,nparam,srcetype
                                                                                                                                                                                                                                                                ... read heating source parameters ...
                                                                                                                              read(inparam,1090) divv, divp, dmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               read(irg,1028) (hx(i),i=1,nx-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                (hy(j),j=1,ny-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                read(inparam, 1007) gridfile
                                                                                                                                                                                                                                                                                                                                                                                                                                                read(inparam,6000) numshow
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ... read grid file name ...
                                                                                                                                                                                                               read(inparam,1006) exprmnt
                                                                                                                                                                                                                                                                                                             format(//,i4,1x,i4,5x,a1)
                                                                                                                                                                                                                                                                                                                                                                                                                ... read display interval
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              format ( (/,14f6.2)
                                                                                                                                                                                                                                                                                               read(inparam, 3000)
                                                              format(//,5(15,1x))
                                                                                                                                               format(//,3(15,1x))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             format(//,26x,i3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 open(unit=irg ,f
read(irg,1027) nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 read(irg,1027) ny
read(irg,1028) (h
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  read(irg,1027) nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                format(/,i3)
                                                                                                                                                                                                                                  format(/,a8)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 format(/,a8)
                                                                                                                                               1090
                                                                                                                                                                                                                                                                                                              3000
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a vector field
                                                                                                                                                                                                                                                                                                                                   common /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                       common /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                + cx2(i)*f1(i, j,k)
+ cx3(i)*f1(i+1,j,k) )
cy1(j)*f2(i,j-1,k)
+ cy2(j)*f2(i, j,k)
+ cy3(j)*f2(i, j,k)
                                                                                                                                                                                                                          parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                    cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                                /cx/cx1(nxmax), cx2(nxmax), cx3(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         cz3(k)*f3(i,j,k+1)
                                                                                                                                                                                                                                                                                                                                                                                                       cy4(nymax),cy5(nymax),cy6(nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                        cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                    common /cy/cyl(nymax),cy2(nymax),cy3(nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                    common /cz/czī(nzmax),cz2(nzmax),cz3(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          , k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      c22(k)*f3(i,j,k
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      cz1(k)*f3(i,j
                                                                                                                                                        *** calculate divergence of
                                                                                  subroutine div(f1,f2,f3,head,divlog)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        dimension fl(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        f2(nxmax,nymax,nzmax),
f3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 aux2d(i,j) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            20 k=2, nzml
do 25 i=2, nxml
do 25 j=2, nyml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 10 i=2, nxml
do 10 j=2, nym1
do 10 k=2, nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          aux2d(i,j)
                                                                                                                                                                                                                                                                                              character*15 head
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if(divlog) then
do 15 i=1, nx
do 15 j=1, ny
                                                                                                                                                                                                                                                            logical divlog
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                                                                                                                                                                                                                                                                                   common
                                 return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      10 continue
                                                 end
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ဝှ
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               O
                                                                                                                                                                                                                                                                                   common /reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,ccp,
                                                                                                                                                                                                                                                                                                                                                                                                          .. random disturbance (between -pdist to +pdist) of psi field
                                                                                                                                                                            *** disturb stream function field at random ***
                                                                                                                                                                                                                                                                                                                      /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                p1(i,j,k) = p1(i,j,k) + p1(i,j,k) *genran(ii,jj) *pdist
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         p2(i,j,k) = p2(i,j,k)+p2(i,j,k)*genran(ii,jj)*pdist
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               p_3(i,j,k) = p_3(i,j,k)+p_3(i,j,k)*genran(ii,jj)*pdist
write(*,*)'Data input done. INPARAM is closed.'
                                                                                                                                                                                                                                                parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                       cct, tmax, pdist, rtime
                                                                                                                                                                                                                                                                                                                                       /p1/p1(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                       /p2/p2 (nxmax, nymax, nzmax)
                                                                                                                                                                                                                                                                                                                                                                     common /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     .. recalculate velocity
                                                                                                        subroutine distb
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 10 i=2,nxml
do 10 j=2,nyml
do 10 k=2,nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 20 i=2,nxm1
do 20 j=2,nym1
do 20 k=2,nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 30 i=2,nxm1
do 30 j=2,nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 30 k=2,nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                            pl field
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     p2 field
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           .. p3 field
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        call veloc
                                                                                                                                                                                                                                                                                                                       common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                    return
                                                                                                                                                                                                                                                                                                                                         common
                                                                                                                                                                                                                                                                                                                                                          Common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              j j = 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               i i = 1
                                                       end
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             20
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0 0 0

0 0 0

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dimension a(np,np),b(np,mp),ipiv(nmax),indxr(nmax),indxc(nmax)
                                                                                              write(*,*)'heating source is not a function of temperature.'
                                                                                                                                                                                                                                                                                             Gauss-Jordan elimination ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if(ipiv(j).ne.1)then
do 12 k=1,n
   if (ipiv(k).eq.0) then
   if (abs(a(j,k)).ge.big)then
   big=abs(a(j,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                else if (ipiv(k).gt.1) then
                                                                                                                                                                                                                             subroutine gaussjdn(a,n,np,b,m,mp)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   pause 'singular matrix'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ipiv(icol)=ipiv(icol)+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            a(irow, 1) = a(icol, 1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          b(irow, l) = b(icol, l)
b(icol, l) = dum
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (irow.ne.icol) then
                                                                                                                                                                                                                                                                                                                                                            parameter (nmax=50)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               a(icol,1)=dum
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            dum=b(irow, 1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            dum=a(irow,1)
                                                                 write(*,*) line
                                                                                                                                                               write(*,*) line
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   icol=k
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      irow=j
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 15 l=1,m
                                                                                                                               line(i:i)='_'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 14 l=1,n
                  do 80 i=1,71
                                  line(i:i)='_
                                                                                                                  do 98 i=1,71
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   end i f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                         do 11 j=1,n
                                                                                                                                                                                                                                                                                                                                                                                                                                        do 22 i=1,n
                                                                                                                                                                                                                                                                                                                                                                                                                                                        big=0.
do 13 j=1,n
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                      ipiv(j)=0
                                                     continue
                                                                                                                                                  continue
     continue
                                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                endi f
                                                                                   return
                                                                                                                                                                                  return
     10
                                                   80
                                                                                                   66
                                                                                                                                                  98
                                                                                                                                                                                                                                                                                                                                                                                                                         11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  12
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              14
                                                                                                                                                                                                                                                 0000000
                                                                                                                                                                                                                                            draw the heating-temperature curve at specifed point
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  write(*,40) pointmin,(pointmin+pointmax)/2.,pointmax
format(1x,t1,f8.2,t33,f8.2,t68,f8.2)
write(*,50) ''','''
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if (pointmax.lt.points(i)) pointmax=points(i)
if (pointmin.gt.points(i)) pointmin=points(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(*,*) 'heating curve of ',exprmnt
                                                                                                                                                                                                                                                                                                                                            /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (pointmax .eq. pointmin) goto 99
              call mprtz(aux2d,head,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                format(2x,t2,a1,t35,a1,t70,a1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          position=nint(ay*points(i)+by)
                                                                                                                                                                                                                                                                                                            character line*117, exprmnt*8
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         line(position:position)='.'
                                                                                                                                                                                                                                                                                                                                                                         common /pst/pstx,psty,pstz
common /point/points(200)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ay=69./(pointmax-pointmin)
                                                                                                                                                                                                                                                                                             integer drawstep, position
                                                                                                                                                                                                                                                                                                                                                                                                          common /timestep/timestep
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(*,70)line ,txtemp
format(1x,a71,t72,f5.2)
                                                                                                                                                                                                                                                                                                                           common /exprmnt/exprmnt
                                                                                                                                                                                                                                                                                                                                                          common /draw/drawstep
                                                                              call maxval(aux,head)
                                                                                                                                                                                              subroutine drawcurv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          txtemp=txtemp+0.5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                by=1.-ay*pointmin
                                                                                                                                                                                                                                                                                                                                                                                                                        pointmax=-10000.
 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(*,*) line
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            line(70:70) = 11
                                                                                                                                                                                                                                                                                                                                                                                                                                        pointmin=10000.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 20 i=1,200
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             line(1:1) = '|'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              line(i:i)='__'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 60 i=1,70
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 10 i=1,76
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             txtemp = -2.
                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                             common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           line='
                                                                                                               return
                                                                                                                               end
25
                              20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   40
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*** calculate local and average heat transfer coefficients ***
                                                                                                                                                                                                                                                  common /reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,ccp,
                                                                                                                                                                                                                                                                              /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                            /t/theta(nxmax,nymax,nzmax)
/aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                                                                                                                    common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     , j, k)
                                                                                                                                                                   parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                          hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    -cxf(1,2)*theta(2,j,k)
-cxf(1,3)*theta(3,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       = -cxf(1,1)*theta(1,j,k)
                                                                                                                                                                                                                                                                                                                                               /tbfdc/cxf(2,3),cyf(2,3),czf(2,3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 120 j=1, ny
do 120 k=1, nz
aux2d(j,k) = +cxf(2,1)*theta(nx
                                                                                                                                                                                                                                                                  cct, tmax, pdist, rtime
                                                                                                                                                                                                                                                                                          /h/hx(max), hy(max),hz(max),
                                                                                                                                                                                                                                                                                                                     /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    .. calculate local Nusselt numbers
                                                                                                                                                                                                                                                                                                                                                                                                    dimension tint(max),tt(max)
                                                                                                                                                                                                                                                                                                                                /mapcom/mnx, mny, mnz
                                                                                                                                                                                                                                                                                                                                                                                                                              .. x = 0 and x = arx walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .eq. nx) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       elseif(i .eq. nx) then
                                                                                                                                                                                                          character locate*3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       aux2d(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 100 i=1,nx,nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 110 k=1, nz
                                                                                                                                                                                             character*15 head
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   11(i .eq. 1) then
locate = ' 0 '
elseif(i .eq. nx)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if(i .eq. 1) then
do 110 j=1, ny
                                                     subroutine htc
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             locate = 'arx'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                continue
               return
                                                                                                                                                                                                                                                                               common
                                                                                                                                                                                                                                                                                             COMMOD
                                                                                                                                                                                                                                                                                                                      common
                                                                                                                                                                                                                                                                                                                                                                            COMMON
                                                                                                                                                                                                                                                                                                                                    common
                                                                                                                                                                                                                                                                                                                                                               common
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                            end
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                                                                     0 0 0 0 0 0 0
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     generates random numbers between -1 and 1
                                                     if (a(icol,icol).eq.0.) pause 'singular matrix.'
pivinv=1./a(icol,icol)
                                                                                                                                                                                                                                                                            do 19 1=1,m
b(11,1)=b(11,1)-b(icol,1)*dum
                                                                                                                                                                                                                                                  a(11,1)=a(11,1)-a(icol,1)*dum
                                                                                                                                                                                                                                                                                                                                                                                                                    a(k, indxr(1)) =a(k, indxc(1))
                                                                                                            a(icol, 1) = a(icol, 1) *pivinv
                                                                                                                                                    b(icol,1)=b(icol,1)*pivinv
                                                                                                                                                                                                                                                                                                                                                                          if(indxr(1).ne.indxc(1))then
do 23 k=1,n
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       genran=2.0*(rjj/32767)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              function genran(ii,jj)
                                                                                                                                                                                                                                                                                                                                                                                                                                a(k, indxc(1)) =dum
                                                                                                                                                                                                                                                                                                                                                                                                      dum=a(k,indxr(1))
                                                                                                                                                                                            if(ll.ne.icol)then
                                                                                                                                                                                                       dum=a(11,icol)
a(11,icol)=0.
do 18 l=1,n
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  jj=ii*899
if(jj.lt.0) then
                                                                                  a(icol,icol)=1.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        integer*2 ii,jj
                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                            do 24 1=n,1,-1
                                                                                                                                                                                                                                                                                                            continue
                            indxr(i)=irow
                                          indxc(i)=icol
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              1 j = j j + 32767 + 1
                                                                                                                                                                               21 ll=1, n
   continue
                                                                                              do 16 l=1,n
                                                                                                                                                                                                                                                                                                                                                                                                                                                continue
                                                                                                                                       do 17 l=1,m
                                                                                                                            continue
                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                       endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        return
              endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            rjj=jj
                                                                                                                                                                                                                                                                                                                                                                                                                                                            endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     end
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calculate the average of the z-averaged Nusselt numbers, nuzx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            2210 format(//, wall y = ',a3,': average Nusselt number along',
+ 'lines parallel to the z-axis:-',/',19x,'i',9x,'nu',//,
                                                                                                                                                                                                                                                                                                                                                                                                                                            calculate the z-averaged Nusselt numbers, \operatorname{nuz}(x)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write (ireport,2210) locate, (i, tt(i), i=1,nx)
              map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                                                                                                                                                                       .. calculate local Nusselt numbers
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call simpsn (tint,nz,hz,tt(i))
                                                                                        and y = ary walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           tint(k) = aux2d(i,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             (17x, i3, 6x, 1p, g12.4))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     call simpsn (tt,nx,hx,tbar)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call mprty(aux2d,head,1)
                                                                                                                                                                            elseif(j .eq. ny) then
                                                                                                                                                                                                                                                                                                                                                                                    elseif(j .eq. ny) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     local nu
                                                                                                                 do 200 j=1,ny,nym1
                                                                                                                                                                                                                                                                                              do 210 k=1, nz
                                                                                                                                                                                                                                                                                                                                                                                                                do 220 i=1, nx
do 220 k=1, nz
                                                                                                                                                  .eq. 1) then
                                                                                                                                                                                                                                                                   f(j .eq. 1) then
do 210 i=1, nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 231 k=1,nz
                                                                                                                                                                 locate = '0'
                                                                                                                                                                                         locate = 'ary'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 232 i=1,nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                       0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       head = '
                                            continue
                                                                                         н
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     232 continue
                            endi f
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                                                                                                                                                                                                                                                                                                                                                        210
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             000
                                                                                                                                                                                                                                                                                                                            calculate the average of the z-averaged Nusselt numbers, nuzy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         calculate the average of the y-averaged Nusselt numbers, nuyz
                                                                                                                                                                                                                                                                write (ireport,2110) locate, (j, tt(j), j=1,ny)
cormat(//, wall x = ',a3,': average Nusselt number along'
                                                                                                                                                                                                                                                                                                                                                                                                   format(//,15x,'the average of those averages is ',1p,g12.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             format(//15x,'average Nusselt number along lines parallel'
+' to the y-axis:-'//19x,'k',9x,'nu'/(17x,i3,6x,g12.4))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  2140 format(//15x, the average of those averages is ',g12.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       format(1h1,10x,5('*'),' contour map of ',a15,5('*'))
                                                                                                                 .. calculate the z-averaged Nusselt numbers, \text{nuz}\left(\gamma\right)
                                                                                                                                                                                                                                                                                                                                                                                                                                 .. calculate the y-averaged Nusselt numbers, nuy(z)
+cxf(2,2)*theta(nxm1,j,k)
+cxf(2,3)*theta(nxm2,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 write (ireport,2130) (k, tt(k), k=1,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .. plot contour map only if nuyz > .1
                                                                                                                                                                                                       call simpsn (tint,nz,hz,tt(j))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      call simpsn (tint,ny,hy,tt(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            head = ' nu at x = '//locate
                                                                                                                                                                             tint(k) = aux2d(j,k)
                                                                                                                                                                                                                                                                                                                                                        call simpsn (tt,ny,hy,tbar)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           tint(j) = aux2d(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        call simpsn (tt,nz,hz,tbar)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write (ireport,2150) head
                                                                                                                                                                                                                                                                                                                                                                                       write (ireport,2120) tbar
                                                                                      call mprtx(aux2d,head,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write (ireport,2140) tbar
                                                                       local nu
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (tbar.gt..1) then
                                                                                                                                             do 132 j=1,ny
do 131 k=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 141 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 142 k=1,nz
                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            continue
                             continue
                                                                       head = '
                                                                                                                                                                                                                         continue
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                                           endi f
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calculate the average of the y-averaged Nusselt numbers, nuyx
                                                                                                                                                                                                                                                                                                                           average Nusselt number along',
z-axis:-',//,19x,'i',9x,'nu',//,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              . calculate the average of the x-averaged Nusselt numbers, nuxy
                                                                                                                                                                                                                                                                                                                                                                                                                                                       format(//,15x, the average of those averages is ',1p,g12.4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write (ireport,2330) (j, tt(j), j=1,ny)
format(//15x,'average Nusselt number along lines parallel',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 +' to the x-axis:-'//19x,'j',9x,'nu'//(17x,i3,6x,gi2.4))
                                                    +czf(2,2)*theta(i,j,nzml)
+czf(2,3)*theta(i,j,nzm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      format(//15x,'the average of those averages is ',g12.4)
                                                                                                                                                                      .. calculate the y-averaged Nusselt numbers, \text{nuy}\left(x\right)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     .. calculate the x-averaged Nusselt numbers, \max(y)
                                                                                                                                                                                                                                                                                                        write (ireport,2310) locate, (i, tt(i), i=1,nx)
                                       = czf(2,1)*theta(i,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    .. plot contour map only if nuxy >
                                                                                                                                                                                                                                                            call simpsn (tint,ny,hy,tt(i))
                                                                                                                                                                                                                                                                                                                   call simpsn (tint,nx,hx,tt(j))
                                                                                                                                                                                                                                  tint(j) = aux2d(i,j)
                                                                                                                                                                                                                                                                                                                                                                                                            call simpsn (tt,nx,hx,tbar)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               tint(i) = aux2d(i,j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           call simpsn (tt,ny,hy,tbar)
                                                                                                                                                                                                                                                                                                                                                                                                                                        write (ireport,2320) tbar
                                                                                                                                         call mprtz(aux2d,head,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write (ireport,2340) tbar
                    do 320 j=1, ny
aux2d(i,j)
                                                                                                                            local nu
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (tbar.gt..1) then
                                                                                                                                                                                                                  do 331 j=1,ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 341 i=1,nx
      do 320 i=1,
                                                                                                                                                                                                   332 i=1,nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 342 j=1,ny
                                                                                                                                                                                                                                                   continue
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                                                                              continue
                                                                                                                            head = '
                                                                                                                                                                                                                                                                          332 continue
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                                                                                                                                                                                                                                                           zxnu
write (ireport,2220) tbar
format(//,15x,'the average of those averages is ',1p,g12.4)
                                                                                                                                                                                write (ireport,2230) (k, tt(k), k=1,nz)
format(//15x,'average Nusselt number along lines parallel',
                                                                                                                                                                                                                                           calculate the average of the x-averaged Nusselt numbers,
                                                                                                                                                                                                             +' to the x-axis:-'//19x,'k',9x,'nu'//(17x,i3,6x,gi2.4))
                                                                                                                                                                                                                                                                                                                  format(//15x,'the average of those averages is ',g12.4)
                                                            uux(z)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            -czf(1,2)*theta(i,j,2)
-czf(1,3)*theta(i,j,3)
                                             calculate the x-averaged Nusselt numbers,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           = -czf(1,1)*theta(i,j,1)
                                                                                                                                                                                                                                                                                                                                                                                                                       call map(aux2d,x,z,nx,nz,mnx,mnz,arz)
                                                                                                                                                                                                                                                                                                                                                .. Plot contour map only if nuxz >
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                .. calculate local Nusselt numbers
                                                                                                                                   call simpsn (tint,nx,hx,tt(k))
                                                                                                                                                                                                                                                                                                                                                                                             nu at y = '//locate
                                                                                                         tint(i) = aux2d(i,k)
                                                                                                                                                                                                                                                                      call simpsn (tt,nz,hz,tbar)
                                                                                                                                                                                                                                                                                                                                                                                                          write (ireport,2150) head
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 \dots z = 0 and z = arz walls
                                                                                                                                                                                                                                                                                                   write (ireport,2240) tbar
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             then
                                                                                                                                                                                                                                                                                                                                                                            if (tbar.gt..1) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if(k .eq. 1) then
do 310 i=1, nx
do 310 j=1, ny
aux2d(i,j) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 300 k=1,nz,nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if(k \cdot eq. 1) then locate = '0'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ·ed· nz)
                                                                                        do 241 i=1,nx
                                                                        do 242 k=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ocate = 'arz'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                elseif(k .eg.
                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                             head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          elseif (k
                                                                                                                                                      continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                        endif
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              2220
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format(///,13x,'*** fields have been initialised ***')
                                                       zero
                                                set velocity boundary conditions to
                                                                                       = arx walls
                                                                                                                                                                                                                                                                                                                                                                               walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          . initialise all fields to zero
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        0.0
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,2010)
                                                                                                                                           u(nx,j,k)
v(1,j,k)
v(nx,j,k)
w(1,j,k)
w(nx,j,k)
                                                                                                                                                                                                                                     y = 0.0 and
                                                                                                                                                                                                                                                                                                                                                                                              do 30 i=1, nx
do 30 j=1, ny
u(i,j, 1) =
u(i,j,nz) =
v(i,j, 1) =
v(i,j,nz) =
w(i,j,nz) =
w(i,j,nz) =
                                                                                                                                                                                                                                                                                                                                                                           0.0 and
                                                                                                                                                                                                                                                                                            u(i,ny,k)
v(i, 1,k)
v(i,ny,k)
w(i, 1,k)
w(i,ny,k)
                                                                                                                       .0 k=1, nz
u( 1,j,k)
                                                                                                                                                                                                                                                        20 i=1, nx
do 20 k=1, nz
                                                                                                                                                                                                                                                                                 u(i, 1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     u(i,j,k)
v(i,j,k)
w(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 40 i=1, nx
do 40 j=1, ny
do 40 k=1,
                                                                                   0.0
                                                                                                      do 10 j=1, ny
do 10 k=1,
                        if (reed) then
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zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb
common /tbi/ixly,ixlyh,ixlzl,ixlzh,ixhyl,ixhyh,ixhzl,ixhzh,
iylxl,iylxh,iylzl,iylzh,iyhxl,iyhxh,iyhzl,iyhzh,
izlxl,izlxh,izlyl,izlyh,izhxl,izhxh,izhyl,izhyh
                                                                                                                                                                  vorticity and temperature fields ***
                                                                                                                                                                                                                                                                                                                 /tbr/xlci,xlcg,xlca,xlcb,xhci,xhcg,xhca,xhcb,
                                                                                                                                                                                                                                                                                                                                                                                                                                 /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                  *** initialise velocity, vector potential,
                                                                                                                                                                                                                                                                                /logc/reed,rite,strt,dist,heat,nuss,tran/logtbc/ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                   common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                           parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    p3, if rquired
                                                                                                                                                                                                                                logical reed,rite,strt,dist,heat,nuss,tran
logical ixl,ixh,iyl,iyh,izl,izh
                    call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                        hxold(max),hyold(max),hzold(max)
                                                                                                                                                                                                                                                                                                      /intcom/itercmpo, norun, mainiter
                                                                                                                                                                                                                                                                                                                                                                                   common /velbc/xlu,xlv,xlw,xhu,xhv,xhw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /p3old/p3old(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /p2old/p2old(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                 ylu,ylv,ylw,yhu,yhv,yhw,
zlu,zlv,zlw,zhu,zhv,zhw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /ploid/ploid(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /told/told(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                            /h/hx(max),hy(max),hz(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /p2/p2(nxmax,nymax,nzmax)/p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          /pl/pl(nxmax,nymax,nzmax)
 nu at z = '//locate
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      w(nxmax,nymax,nzmax)
        write (ireport,2150) head
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    p1,
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head =
                                           300 continue
                                                                                                                                                                                                                                                                                                                 common
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                                 endi f
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hxo(max),hyo(max),hzo(max),hxn(max),hyn(max),hzn(max),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        interpolate t from (nx,nx,nz) to (nxnew,nynew,nznew) ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          sizes. the method used is linear interpolation of the velocity components and temperature corresponding to the old mesh sizes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              temperature at the mesh points corresponding to the new mesh
                                                                                                                                                                                                                                                                                                                                                                                                                                                               subroutine interp(nx,ny,nz,nxnew,nynew,nznew,hxo,hyo,hzo,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            dimension xo(max),yo(max),zo(max),xn(max),yn(max), מיול dimension xo(max),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              subroutine inter calculates the velocity components and
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      please see notes on velvec for method of interpolation
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 inttl, intt2, intt3, intt4, intt5, intt6
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   parameter(nxmax=51, nymax=51, nzmax=51, max=51)
                                                                                                                         arz
                                                                                                                                                                            do 140 j=izhyl, izhyh
theta(i,j,nz) = zhci
                        do 130 i=izlxl, izlxh
do 130 j=izlyl, izlyh
theta(i,j,1) = zlci
                                                                                                                         7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 hxn, hyn, hzn, t)
                                                                                                                   . isothermal condition on
                                                                                                                                                                                                                                                                                                                                                             0
                                                                                                                                                             do 140 i=izhxl, izhxh
                                                                                                                                                                                                                                                                                                               do 150 i=1, nx
do 150 j=1, ny
do 150 k=1, nz
                                                                                                                                                                                                                                                                                     .. no heating at all
                                                                                                                                                                                                                                                                                                                                                          theta(i,j,k)
            if (izl) then
                                                                                                                                               if (izh) then
                                                                           continue
                                                                                                                                                                                                            continue
                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                      endi f
                                                                                                                                                                                                                                                                                                                                                                                                                       return
                                                                                                                                                                                                                                                                                                                                                                                         endi f
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   O
                                                                                                                                                                                                .. set temperature boundary conditions (if required)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   0.0 wall
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   .. isothermal condition on z = 0.0 wall
                                                                                                                                                                                                                                                                0.0
                                                                                                                                                                                                                                                                                                                                                                                                    arx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ary
                                                                                                                                                                                                                                                                          if (ix1) then
    do 90 j=ixlyl, ixlyh
    do 90 k=ixlzl, ixlzh
    theta(1,j,k) = xlci
                                                                                                                                                                                                                                                                 IJ
                                                                                                                                                                                                                                                                                                                                                                                                                                       do 100 j=ixhyl, ixhyh
do 100 k=ixhzl, ixhzh
theta(nx,j,k) = xhci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     н
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .. isothermal condition on y =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 120 i=iyhx1, iyhxh
do 120 k=iyhz1, iyhzh
theta(i,ny,k) = yhci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 110 i=iylx1, iylxh
  do 110 k=iyl21, iyl2h
  theta(i,1,k) = ylci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              .. isothermal condition on y
                                                                                                                                                                                                                                                           .. isothermal condition on x
                                                                                                                                                                                                                                                                                                                                                                                              .. isothermal condition on x
                                                                                                              = tstrt
= 3.0
      pl(i,j,k)
p2(i,j,k)
p3(i,j,k)
plold(i,j,k)
p2old(i,j,k)
p3old(i,j,k)
                                                                                                         theta(i,j,k)
told(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          if (iyl) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (iyh) then
                                                                                                                                                                                                                            if(heat) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
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                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    endif
                                                                                                                                                                   endi f
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+ t(io+1,ny,ko)
                                       + t(io+1,jo,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           + t(io+1,1,ko)
                                                                                                                                                                         + t(io,jo,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              aux(i,nynew,k) = ((inttl - intt2) * ratioz) + intt2
                                                                                                                                                                                    aux(i,j,nznew) = ((inttl - intt2) * ratiox) + intt2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   intt1 = ((t(io+1,ny,ko+1) - t(io+1,ny,ko)) * ratioz)
                intt1 = ((t(io+1,jo+1,1) - t(io+1,jo,1)) * ratioy)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    intt1 = ((t(io+1,1,ko+1) - t(io+1,1,ko)) * ratioz)
                                                intt2 = ((t(io, jo+1, 1) - t(io, jo, 1)) * ratioy) +
                                                                                                                                                 intt2 = ((t(io,jo+1,nz) - t(io,jo,nz)) * ratioy)
                                                                                 aux(i,j,1) = ((intt1 - intt2) * ratiox) + intt2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  intt2 = ((t(io,1,ko+1) - t(io,1,ko)) * ratioz) +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  intt2 = ((t(io,ny,ko+1) - t(io,ny,ko)) * ratioz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  aux(i,1,k) = ((intt1 - intt2) * ratiox) + intt2
                                                                                                                                                                                                                                                                                                                                                                                                                                         (-xo(io)+xo(io+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                        (-zo(ko)+zo(ko+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ratioy = (ynew-yo(jo)) / (-yo(jo)+yo(jo+1))
                                                                                                                                                                                                                                                  calculate values of t at the planes i=1 and i=m
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 calculate values of t at the planes j=1 and j=n
                                                                                                                                                                                                                                                                                                                                                                                   call search(xnew,xo,io,nx)
                                                                                                                                                                                                                                                                                                                                                                                                    search(znew,zo,ko,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                  ratiox = (xnew-xo(io)) /
ratioz = (znew-zo(ko)) /
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call search(ynew,yo,jo,ny)
call search(znew,zo,ko,nz)
                                                                      t(io,jo,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        t(io,1,ko)
                                                                                                                                                                                                                                                                                             do 75 i=1, nxnew
do 75 k=1, nznew
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 80 j=1, nynew
do 80 k=1, nznew
                                                                                                                                                                                                                                                                                                                                       xnew = xn(i)
                                                                                                                                                                                                                                                                                                                                                    znew = zn(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      ynew = yn(j)
znew = zn(k)
                                                                                                                                                                                                                                                                                                                                                                                                    call
                                                                                                                                                                                                70 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                75 continue
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                                                                                                                                                                                                                  ပပ်
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t(nxmax,nymax,nzmax),aux(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      = (xnew-xo(io)) / (-xo(io)+xo(io+1))
= (ynew-yo(jo)) / (-yo(jo)+yo(jo+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  calculate values of t at the planes k=1 and k=1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call search(xnew,xo,io,nx)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  call search(ynew,yo,jo,ny)
                            ...subroutine inter begins
                                                                                                                                                                                                                 xo(i+1) = xo(i) + hxo(i)
                                                                                                                                                                                                                                                                                  yo(j+\bar{1}) = y\bar{o}(j) + hyd(j)
                                                                                                                                                                                                                                                                                                                                do 35 k=1, nz-1
zo(k+1) = zo(k) + hzo(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 xn(i+1) = xn(i) + hxn(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   yn(j+1) = yn(j) + hyn(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    \operatorname{zn}(k+1) = \operatorname{zn}(k) + \operatorname{hzn}(k)
                                                                  - - uxnew - 1
= nynew - 1
= nznew - 1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 do 55 j=1, nynew-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 45 i=1, nxnew-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 65 k=1, nznew-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 70 i=1, nxnew
do 70 j=1, nynew
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    xnew = xn(i)
                                                                                                                                                                                                                                                                 do 25 j=1, ny-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      ynew = yn(j)
                                                                                                                                                                                                do 15 i=1, nx-1
                                                                                                                                 0.00
                                                                                                                                                                                                                                                                                                                                                                                                  xn(1) = 0.0

yn(1) = 0.0

zn(1) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ratiox
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ratioy
                                                                                                                                                                                                                                                                                                                                                                   continue
                                                                                                                                                                                                                                    continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                nxnewl
                                                                                                 nznew1
                                                                                 nynewl
                                                                                                                                                              20(1)
                                                                                                                                xo(1)
yo(1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 52
                                                                                                                                                                                                                                 15
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/reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,ccp,
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/porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos
/epsonnu/epson,xll,annu,gravity,ddd ,keff
                                                 aux(i,j,k) = ((intt6 - intt5) * ratioz) + intt5
              intt6 = ((intt1 - intt2) * ratiox) + intt2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      'geom/nx, ny, nz, nxm1, nym1, nzm1, nxm2, nym2, nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                                                                                                                                                                                                                                            *** solution control routine ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /logc/reed,rite,strt,dist,heat,nuss,tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                             parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ogical reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /test/testp1,testp2,testp3,testt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             cct, tmax, pdist, rtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       integer timestrt, timerun, timecal
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /vel/u(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /pl/pl(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       'p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  w(nxmax,nymax,nzmax)
                                                                                                                                                                           t(i,j,k) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                 /mapcom/mnx,mny,mnz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  logical blup, cgd, trace
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /itheta/itheta
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /logi/blup, cgd
                                                                                                                                    do 90 j=1, nynew
do 90 k=1, nznew
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /phierr/phierr
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /numcom/numit
                                                                                                                                                                                                                                                                                    subroutine iterat
                                                                                                                      do 90 i=1, nxnew
                                                                                  85 continue
                                                                                                                                                                                            90 continue
                                                                                                                                                                                                                                   return
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              new mesh sizes using values of t at the eight mesh points
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           calculate t1 at the new mesh point corresponding to the |
                                                                                                                                                                       + t(nx, jo+1, ko)
                                                             + t(1, jo+1, ko)
                                                                                                                                                                                                           aux(nxnew,j,k) = ((intt1 - intt2) * ratioy) + intt2
                                                                                                                                                                                                                                                                                                                                                                                                                                     calculate position of new mesh point relative to old
                                                                                               aux(1,j,k) = ((intt1 - intt2) * ratioy) + intt2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               corresponding to the old mesh sizes surrounding it
                                                                                                                                          intt1 = ((t(nx, jo+1, ko+1) - t(nx, jo+1, ko)) * ratioz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   ((t(io+1,jo+1,ko+1) - t(io+1,jo,ko+1)) * ratioy)
                               intt1 = ((t(1,jo+1,ko+1) - t(1,jo+1,ko)) * ratioz)
                                                                                                                                                                             intt2 = ((t(nx,jo,ko+1) - t(nx,jo,ko)) * ratioz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           (-yo(jo)+yo(jo+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              (-zo(ko)+zo(ko+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    t(io+1,jo,ko+1)
((t(io,jo+1,ko+1) - t(io,jo,ko+1)) * ratioy)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          (-xo(io)+xo(io+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ((t(io+1,jo+1,ko) - t(io+1,jo,ko)) * ratioy)
                                                                   intt2 = ((t(1,jo,ko+1) - t(1,jo,ko)) * ratioz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              intt5 = ((intt3 - intt4) * ratiox) + intt4
  (-zo(ko)+zo(ko+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            = ((t(io,jo+1,ko)-t(io,jo,ko)) * ratioy)
                                                                                                                                                                                                                                                                                       calculate values of t for internal nodes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              call search(xnew,xo,io,nx)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               call search(ynew,yo,jo,ny)
call search(znew,zo,ko,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ratiox = (xnew-xo(io)) /
ratioy = (ynew-yo(jo)) /
ratioz = (znew-zo(ko)) /
= (znew-zo(ko)) /
                                                                                                                                                                                                                                                                                                                                        do 85 i=2, nxnew1
do 85 j=2, nynew1
do 85 k=2, nznew1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           = xn(i)
= yn(j)
= zn(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              t(io+1,jo,ko)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          t(io,jo,ko+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               t(io,jo,ko)
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ratioz
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format(/'-- maximum temperature iterations reached.--')
                                                                                                                                                                                                                                                                format(/'temp solution has diverged in',i4,' its. ',/)
                                                                                                                                                                                                                                                                                                                                                                                                if ((testp2.lt.ccp).and.(testp3.lt.ccp)) goto 4001
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if ( (testt.gt.big).or.(testp2.gt.big).or
                                                                                                                 call ttime(.false., .true., .false.)
rtime = real(timerun)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    call temperature solution subroutines
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             (testp3.gt.big) ) blup = .true
                        .. maximum iteration limit reached
                                                                                                                                                                                                                                                                                                                                                                                                                                                    call velocity solution subroutines
                                                                                                                                                                                                                                                 write(ireport,2061) itheta
                                                if(itheta.ge.mainiter) then
                                                                                                                                                                                                                                                                                                                                             do 4000 nump2p3=1,iterpp
                                                                                                                                                                                                                                      write(*,2061) itheta
                                                                                                                                                                                                                                                                                                                     ... update each field
                                                                            write(ireport,2051)
                                                                                                                                                                                                .. solution diverged
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               call iterout(itheta)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ... transient results
                                                                                                                                             numit = itheta
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if(sumdivt.lt.cct)
                                                             write(*,2051)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              call tsolp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                             call veloc
                                                                                                                                                                                                                       if(blup)then
                                                                                                                                                                                                                                                                                                                                                          call plsolp
call p2solp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     cgd= .true.
                                                                                                                                                                                                                                                                                                                                                                                     call p3solp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           call vbc
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           call tbc
                                                                                                                                                          return
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         format(/'temp solution has converged. iteration number =',
                                                                                                                                                                                                                                                                                                                                                                                                     running',t12,' cpu',t17,'percentage')
time',t12,'time',t17,' completed',t28,
                                                                                                                                                                                                                                                                                                                                                                                                                                   test_p3',
                                                             common /timestrt/timestrt,timerun,timecal
                                                                                        ... initialise timer, counters and flags
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     numit = itheta
call ttime(.false., .true., .false.)
rtime = real(timerun)
                                                                                                                                                                                                                                                                                                                                                                                                                                              t_err',/)
                                                                                                                                                                                                                                                                                                                                                                                                                               test_p2',t44,'
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write(ireport,2031) itheta
/timestep/timestep
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           advance temperture field
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 --- iteration starts ---
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 200 itheta=1, mainiter
                                     /sumdivt/sumdivt
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format(t1,' running'
             /iterpp/iterpp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           .. solution converged
                        /trace/trace
                                                 common /fig/fig
                                                                                                                                                                                                                                                                                                                                                                                                                              'itheta',t33,'
                                                                                                                                                                                                                                                                  if (heat) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if( cgd ) then
                                                                                                                                                                                        .false.
                                                                                                                                                                                                  blup = .false.
                                                                                                                                                                                                                                                                                                                                                write(*,9000)
write(*,9001)
write(*,9002)
                                                                                                                                                                          trace= .true.
                                                                                                                      0.0
                                                                                                                                                                                                                            testp2 = 1.0 testp3 = 1.0
                                                                                                                                                                                                                                                       sumdivt= 1.0
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if ( ((ithera.ne.1).and.(itheta.lt.11)).or.(itheta.eq.100)
                                                                                                                                                                                                                                                                                     /porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             horiv(3,20,41) common /drwstp/drwstp1, drwstp2, drwstp3, drwstp4, drwstp5, drwstp6, drwstp7, drwstp8, drwstp9, drwstp10, drwstp11, drwstp12
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       /horitemp/horitemp(3,20,41),horiu(3,20,41),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              nu_x_1(nymax,nzmax),nu_x_nx(nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        nu_y_1(nxmax,nzmax),nu_y_ny(nxmax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             nu_z_1(nxmax,nymax),nu_z_nz(nxmax,nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               dimension tint1(max), tint2(max), tt1(max), tt2(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       dimension tint3(max),tint4(max),tt3(max),tt4(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    tint5(max),tint6(max),tt5(max),tt6(max)
                                                                                                                                                                                                                                                                                                                  /epsonnu/epson,xll,annu,gravity,ddd ,keff
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                                                                                                                                              pstx2,psty2,pstz2,pstx3,psty3,pstz3,pstx4,pstx4,pstx4,pstx5,psty5,pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            pstx8, psty8, pstz8, pstx9, psty9, pstz9
                                                                                                                                                                                                                                                                                                                                                                                                                                                  pstx6,psty6,pstz6,pstx7,psty7,pstz7
/tbfdc/cxf(2,3),cyf(2,3),czf(2,3)
                                                                                                                                      /t/theta(nxmax,nymax,nzmax)
                                                          /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                        /pstxyz/pstxl,pstyl,pstzl
                                                                                    v(nxmax,nymax,nzmax),
                                                                                                                                                              /pl/pl(nxmax,nymax,nzmax)
                                                                                                                                                                                    /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                /p3/p3(nxmax,nymax,nzmax)
                                                                                                              w(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    call ttime(start,runng,runend)
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                                                                                                                                                                                                                                                                                                                                                  /pst/pstx,psty,pstz
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                                  /numcom/numit
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                        *** output transient iterate results
                                                                                                                                                                                                                                                                                                                                                                                                                                \mathtt{pstx8}, \mathtt{psty8}, \mathtt{pstz8}, \mathtt{pstx9}, \mathtt{pstz9}, \mathtt{pstz9}, \mathtt{pstz10}, \mathtt{psty10}, \mathtt{psty10}, \mathtt{pstz11}, \mathtt{psty11}, \mathtt{pstz11}
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          'logc/reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /logpvm/vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /fileno/inparam,irg,ireport,itin,itout
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    vzp1,vzp2,vzp3,vzt,vzu,vzv,vzw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                          parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                ,pstx2,psty2,pstz2,pstx3,psty3,pstz3
,pstx4,psty4,pstz4,pstx5,psty5,pstz5
                                                                                                                                                                                                                                                                                                                                                                                                      ,pstx6,psty6,pstz6,pstx7,psty7,pstz7
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            integer timestrt, timerun, timecal, drawstep
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /test/testpl,testp2,testp3,testt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              vxp1, vxp2, vxp3, vxt, vxu, vxv, vxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      common /intcom/itercmpo,norun,mainiter
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myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          mxp1, mxp2, mxp3, mxt, mxu, mxv, mxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /timestrg/timestrg,datestrg
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /h/hx(max), hy(max), hz(max),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                cct, tmax, pdist, rtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        trace, start, runng, runend
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  character timestrg*11,datestrg*9
                                                                                                                                                                                                                                                                    parameter(big=10000000000000000)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /mapcom/mnx, mny, mnz
                                subroutine iterout(itheta)
                                                                                                                                                                                                                                                                                                                            integer pstx1,psty1,pstz1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    phierr/phierr
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /logi/blup,cgd
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       blup, cgd
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          ogical
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   logical
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if ((itheta-1) .eq. int(15.*3600./timestep)) then
                                                                                                                                            int(10.*3600./timestep)) then
                                                                                                                                                                                                                                       then
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                                                                                                                                                                                                                                                                                                                                                                                                                    then
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         then
                                                                                                                                                                                                                                    int(5.*3600./timestep))
                                                                                                                                                                                                                                                                                                                         if ((itheta-1) .eq. int(3600./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                              if ((itheta-1) .eq. int(3300./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if ((itheta-1) .eq. int(3000./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        if ((itheta-1) .eq. int(2700./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              if ((itheta-1) .eq. int(2400./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if ((itheta-1) .eq. int(2100./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            .eq. int(1800./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if ((itheta-1) .eq. int(1500./timestep))
                                                                                                                                                                                                                                 if ((itheta-1) .eq.
                                                                                                                                                .ed.
                                                                                                                                          if ((itheta-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if ((itheta-1)
                                                                                        ok=.true.
endif
                                                                                                                                                                                                                                                                     ok=.true.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ok=.true.
endif
                                                                                                                                                                                                                                                                                                                                                            ok=.true.
                                                                                                                                                                                                                                                                                                                                                                                                                                                   ok=.true.
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                                                                                                                                                                                 ok=.true
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                                                                                                                                                                                              endi f
                   endif
                                                                                                                                                                                                                                                                                        endi f
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                  endi f
                                                                      n = 15
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   endi f
                                                                                                                                                               n=14
                                                                                                                                                                                                                                                   n = 13
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      n = 10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          endif
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                                                                                                                                                                                                                                                                                                                                          n = 12
                                                                                                                                                                                                                                                                                                                                                                                                                                n = 11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             n=9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              9=u
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            collect transient values of velocity ans temperature on central axes
                                                                                                                                             + 100.*real(itheta)/real(mainiter),itheta,testp2,testp3, + testt,sumdivt
                                                                                                                                                                                                                                                                                                                                                                                                  write(*,3001) real(timerun)/3600.,
+100.*real(itheta)/real(mainiter),itheta,testp2,testp3,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              if ((itheta-1) .eq. int(80.*3600./timestep)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      .eq. int(50.*3600./timestep)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           .eq. int(40.*3600./timestep)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  .eq. int(30.*3600./timestep)) then
+ .or.(itheta.eq.50).or.(itheta.eq.20)
+ .or.(mod(itheta,numshow).eq.0)) .and. trace) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         .eq. int(20.*3600./timestep)) then
                                                                                                                                                                              3000 format(2x,f5.1,'h.',t10,f5.2,t18,' ',f5.1,t28,i5,
+ t33,e10.2,t45,e10.2,t57,e10.2,t69,e10.2)
                                                        buffer=real(timerun-timecal)*real(mainiter)/
                                                                                                                             write(*,3000) buffer,real(timerun)/3600.,
                                                                                                                                                                                                                                                                                                                                                                                                                                                      format(1x,t10,f5.2,t18,'',f5.1,t28,i5,
+ t33,e10.2,t45,e10.2,t57,e10.2,t69,e10.2)
                                                                                                                                                                                                                                                                                                                                                                else if (mod(itheta,numshow).eq.0) then
                                                                                                                                                                                                                                                         if(abs(buff) .lt. 0.05) then
                                                                         + (3600.*real(itheta-1))
                                                                                                                                                                                                                                       buff=buffer-buff
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if ((itheta-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if ((itheta-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if ((itheta-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      if ((itheta-1)
                                                                                                                                                                                                                                                                            trace=.false.
                                                                                                                                                                                                                                                                                                                                                                                                                                         testt, sumdivt
                                                                                                                                                                                                                                                                                              else
buff=buffer
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ok=.true.
endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   ok=.true.
endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ok=.true.
endif
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endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ok=.true
                                                                                                                                                                                                                                                                                                                                endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       n = 19
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              n = 18
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  n = 20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   n=17
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theta(pstx10,psty10,pstz10),theta(pstx11,psty11,pstz11)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(iplt,8000)realtime,theta(pstx1,psty1,pstz1)
                       .or.
                                        .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ,theta(pstx2,psty2,pstz2),theta(pstx3,psty3,pstz3)
                                                        .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              , theta(pstx4, psty4, pstz4), theta(pstx5, psty5, pstz5)
, theta(pstx6, psty6, pstz6), theta(pstx7, psty7, pstz7)
, theta(pstx8, psty8, pstz8), theta(pstx9, psty9, pstz3)
                                                                                                                                                                                                                                                      output transient velocity, temperatures and Nu numbers
                                                                                                                                                                                                                                                                                                                                                     (itheta.eq.drwstp7).or.(itheta.eq.drwstp8).or.
(itheta.eq.drwstp9).or.(itheta.eq.drwstp10).or.
(itheta.eq.drwstp11).or.(itheta.eq.drwstp12) ) then
                       vzp2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           calculate average Nusselt numbers on boundary ...
                                        MZA
                                                        mzn
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              u(pstx10,psty10,pstz10)*1000.*alphap/xll,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               u(pstx11,psty11,pstz11)*1000.*alphap/x11
                                                                                                                                                                                                                                                                                                    + (itheta.eq.drwstp1).or.(itheta.eq.drwstp2).or. + (itheta.eq.drwstp3).or.(itheta.eq.drwstp4).or.
                                                        .or.
                                                                                                                                                                                                                                                                                                                                    (itheta.eq.drwstp5).or.(itheta.eq.drwstp6).or.
          .or.
                         .or.
                                         .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                               u(pstx2,psty2,pstz2)*1000.*alphap/xll,
u(pstx3,psty3,pstz3)*1000.*alphap/xll,
u(pstx4,psty4,pstz4)*1000.*alphap/xll,
u(pstx5,psty5,pstz5)*1000.*alphap/xll,
                                                                                                                                                                                                                                                                                                                                                                                                                                  u(pstx1,psty1,pstz1)*1000.*alphap/xll,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                u(pstx6,psty6,pstz6)*1000.*alphap/xll,
u(pstx7,psty7,pstz7)*1000.*alphap/xll,
u(pstx8,psty8,pstz8)*1000.*alphap/xll,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 u(pstx9,psty9,pstz9)*1000.*alphap/xll
                       vzp1
         myp3
                                                        mzt
                                         727
                         or.
                                         . or .
          or.
                                                                                                                                                                                                                                                                                    if ( (mod(itheta,drawstep).eq.0).or.
                                                        or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              format(lx,e9.3,11(1x,f8.6))
format(lx,e9.3,11(1x,f9.3))
        myp2
                                                        mzp3
                           3
M
                                        vzu
                                                                                                                                                                                                                                                                                                                                                                                                                 write(45,8001)realtime,
         .or.
                         or.
                                         .or.
                                                          .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               arx walls
                                                                         .or. mzw) then
                                                                                                         , 24
                                                        mzp2
         myp1
                         mγv
                                         VZt
                                                                                                     do 4000 iireport =1
                        .or.
          .or.
                                         or.
                                                        .or.
                                                                                                                                        ireport=ireport
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            0 and x
                                                                                         ireport = 46
                                                                                                                     call output
                                                                                                                                                                                                     fig=fig+0.5
                                       Vzp3
                                                        mzpl
                         myu
                                                                         m2v
                                                                                                                                                                       ireport =9
                                                                                                                                                        continue
                                                                                                                                                                                      endi f
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ... output first 5 hours contour maps and values of velocity, temperature and vector potential in 30 minutes interval (if required)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           .or.
                                                                                                                       then
                                                                                                                                                                                                     then
                                     then
                                                                                                                                                                                                                                                                                     then
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            vypl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            <u>></u>
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       if (( (itheta-1) .eq. int(fig*3600./timestep))
    .and. (realtime.le. 5.0) ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        horiu(3,n,i) = u((nx+1)/2,(ny+1)/2,i)
horiv(3,n,i) = v((nx+1)/2,(ny+1)/2,i)
horitemp(3,n,i) = theta((nx+1)/2,(ny+1)/2,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             u((nx+1)/2,i,(nz /2)
v((nx+1)/2,i,(nz+1)/2)
w((nx+1)/2,i,(nz+1)/2)
                                                                                                                                                                                                                                                                                                                                                                                                               u(i,(ny+1)/2,(nz+1)/2)
v(i,(ny+1)/2,(nz+1)/2)
w(i,(ny+1)/2,(nz+1)/2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                           horitemp(1,n,i) = theta(i,(ny+1)/2,(nz+1)/2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         horitemp(2,n,i) = theta((nx+1)/2,i,(nz+1)/2)
                             if ((itheta-1) .eq. int(1200./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          vxt
mxp2
                                                                                                                                                                                                                                                                              if ((itheta-1) .eq. int(300./timestep))
                                                                                                                 .eq. int(900./timestep))
                                                                                                                                                                                              if ((itheta-1) .eq. int(600./timestep))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            3XE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       vxp3 .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          mxpl .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         realtime=(itheta-1)*timestep/3600
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         NXW
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         νyt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      if (vxpl .or, vxp2 .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           .or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         or.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        vyp3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          .or. vxw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         .or. mxu
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         or.
                                                                                                              if ((itheta-1)
                                                                                                                                                                                                                                                                                                                                                                                                                   ii
                                                                                                                                                                                                                                                                                                                                                                                                                                  ij
                                                                                                                                                                                                                                                                                                                                                                                                                                                 11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 1003 i=1,
                                                                                                                                                                                                                                                                                                                                                             if (ok) then
                                                                                                                                                                                                                                                                                                                                                                                              do 1000 i=1,
horíu(1,n,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 1001 i=1,
                                                                                                                                                                                                                                                                                                                                                                                                                              horiv(1,n,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           horiu(2,n,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                              horiw(1,n,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            horiv(2,n,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             horiw(2,n,i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        vyp2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ok=.false.
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                                                                                                                                                                                                                                                                                                                ok=.true.
                                                               ok=.true.
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endif
                                                                                                                                n=3
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nuyx
                          nuzx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(inu,400) realtime,tbar1,tbar2,tbar3,tbar4,tbar5,tbar6
                                                                                                                                                                                                                                                                                                                                                                                                                                                     calculate the average of the y-averaged Nusselt numbers,
                          numpers,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    death commodities locations
                                                                                                                                                                                                                                                                                                       calculate the y-averaged Nusselt numbers, nuy(x)
                         z-averaged Nusselt
                                                                                                                                                                                                = -czf(1,1)*theta(i,j,1)
-czf(1,2)*theta(i,j,2)
-czf(1,3)*theta(i,j,3)
) = czf(2,1)*theta(i,j,nz)
+czf(2,2)*theta(i,j,nzml)
+czf(2,2)*theta(i,j,nzml)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                             calculate local Nusselt numbers
                                                                                                                                                                                                                                                                                                                                                                                                  call simpsn (tint5,ny,hy,tt5(i))
call simpsn (tint6,ny,hy,tt6(i))
                                                                                                                                                                                                                                                                                                                                 332 i=1,nx
do 331 j=1,ny
tint5(j) = nu_z_1(i,j)
tint6(j) = nu_z_nz(i,j)
                         calculate the average of the
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                simpsn (tt5,nx,hx,tbar5)
simpsn (tt6,ny,hy,tbar6)
                                                   (tt3,nx,hx,tbar3)
(tt4,nz,hz,tbar4)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    the thermal
                                                                                                       = arz walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  format (1x, e15.9, 6(1x, e9.3))
                                                                                                                                                                                                                                         nu_z_nz(i,j)
                                                                                                                                                                                                 nu_z_1(i,j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  subroutine location
                                                                                                                                                                                        'n
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    showing
                                                                                                                                                                     do 310 i=1, nx
do 310 j=1,
                                                                                                          2
                                                                                                        and
                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                      simpsn
                                                                   simpsn
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                                                                                                                                                                                                                                                                                                                                      nuzy
                                                                                                                                                                                                                                                                                                                                    calculate the average of the z-averaged Nusselt numbers,
                                                                                                                                                                          calculate the z-averaged Nusselt numbers, nuz(y)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     z-averaged Nusselt numbers, nuz(x)
                                                                                         = +cxf(2,1)*theta(nx ,j,k)
+cxf(2,2)*theta(nxml,j,k)
+cxf(2,3)*theta(nxm2,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    = cyf(2,1)*theta(i,ny ,k)
+cyf(2,2)*theta(i,nym1,k)
+cyf(2,3)*theta(i,nym2,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               -cyf(1,1)*theta(i,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          -cyf(1,2)*theta(i,2,k)
-cyf(1,3)*theta(i,3,k)
                                                   = -cxf(1,1)*theta(1,j,k)
-cxf(1,2)*theta(2,j,k)
-cxf(1,3)*theta(3,j,k)
  numbers
                                                                                                                                                                                                                                                                                                                                                                                                                                           .. calculate local Nusselt numbers
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               call simpsn (tint3,nz,hz,tt3(i))
call simpsn (tint4,nz,hz,tt4(i))
                                                                                                                                                                                                                                                                                call simpsn (tint1,nz,hz,tt1(j)) call simpsn (tint2,nz,hz,tt2(j))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       nu_y_ny(i,k)
                                                                                                                                                                                                                           = nu_x_1(j,k)
= nu_x_nx(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         tint3(k) = nu_J_1(i,k)
                                                                                                                                                                                                                                                                                                                                                               (tt1,ny,hy,tbar1)
(tt2,nz,hz,tbar2)
                                                                                                                                                                                                                                                                                                                                                                                                                 y = 0 and y = ary walls
 Nusselt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     nu_y_ny(i,k)
                                                                                          nu_x_nx(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    10 k=1, nz
nu_y_1(i,k)
                                                   nu_x_1(j,k)
calculate locate
                                           пz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                232 i=1,nx
do 231 k=1,nz
                                                                                                                                                                                                                            tint1(k)
tint2(k)
                                                                                                                                                                                                   132 j=1,ny
do 131 k=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        calculate the
                        do 110 j=1, ny
do 110 k=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 210 k=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        tint4(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 210 i=1, nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
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print contour map of variables on the line printer
                                                                                                                                                                                                                write(70,*) 'Locations of thermally dead produce on
                                                                                                                                                                                                                                                                                                                                                                write(70,*) 'Locations of thermally dead produce on
                                                                                                                                                                                                                                                                                                                                                                                                                                                             subroutine map(fun,fv,fh,nv,nh,mnv,mnh,fvlen,fhlen)
                                                                                                                                                                                                                                     write(70,label) ((pnt(i,j,k),j=2,nyml),i=2,nxml)
write(70,*)
                                                                                                                                                                                                                                                                                                                                                                                      write(70,label) ((pnt(i,j,k),k=2,nzml),i=2,nxml)
write(70,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               character star*1,chars(39)*1,table(132,132)*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  parameter(nxmax=51,nymax=51,nzmax=51)
parameter(scale=61./49.)
                                                                                                                                                   0.0) then
                                                                                                                                                                                                                                                                                                     .eq. 0.0) then
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                                                                                                                                                                                                                         x, y central plate.'
                                                                                                                                                                                                                                                                                                                                                                          x, z central plate.'
                                                                                                                                                                                                                                                                                                 if (dthpnt(i,j,k)
pnt(i,j,k)='*'
                                                                                                                                                 if (dthpnt(i,j,k)
pnt(i,j,k)='*'
                                                                                                                           do 100 i=2, nxm1
do 100 j=2, nym1
                                                                                                                                                                                                                                                                  j=(ny+1)/2
do 200 i=2, nxm1
do 200 k=2, nzm1
                                                                                                                                                                                pnt(i,j,k)='.'
                               format(1x,23a1)
                                          format(1x,24a1)
                                                               ormat (1x, 26a1)
                                                                                              ormat(1x,29a1)
                                                                                                                                                                                                                                                                                                                                 pnt(i,j,k)='.'
                                                     ormat(1x,25al)
                                                                          ormat(1x,27a1)
                                                                                     [ormat(1x,28a1)
                      format(1x,22a1
                                                                                                                    k = (nz + 1)/2
                                                                                                                                                                                                                                                                                                                                                                                                          close (70)
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                    common /dthpnt/dthpnt(nxmax,nymax,nzmax),thmldthl,thmldthh
                                /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                           ,file=filename,status='unknown')
character*1 pnt(nxmax,nymax,nzmax)
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                                                                           open(unit=70
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ormat(1x,8a1)
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format(1x,6a1)
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*** print contour map of temperature on the line printer *** |
                                                                                                                                          fint1 = fun(i,j) + ratioy*(fun(i,j+1)-fun(i,j))
fint2 = fun(i+1,j) + ratioy*(fun(i+1,j+1)-fun(i+1,j))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               data chars/' ','1',' ','3',' ','5',' ','7',' ','9',' '/
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      subroutine mapt(fun,fv,fh,nv,nh,mnv,mnh,fvlen,fhlen)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             dimension fun(max,max), fv(max), fh(max), r(11)
                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2030) (table(mi,mj), mj=1, mmnh)
format(5x,128a1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            character star*1, chars(11)*1, table(132,132)*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                        ratiox = (posx - fv(i))/(fv(i+1)-fv(i))
ratioy = (posy - fh(j))/(fh(j+1)-fh(j))
                                                                                                                                                                                            value = fintl + ratiox*(fint2-fint1)
                                          posy = (real(mj)/real(mmnh))*fhlen
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   ... reset size according to scale
                                                                                                                                                                                                                                                                                 table(mi,mj) = chars(k)
                                                        call search(posy, fh, j, nh)
                                                                                                                                                                                                                                                               if (value.le.r(k)) then
        call search(posx, fv, i, nv)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          parameter(scale=61./49.)
                                                                                                                                                                                                                                                                                                                                                                                                   .. print contour ...
                         do 50 mj=2, mmnh-1
                                                                                                                                                                                                                                                                                                                                 go to 45
endif
                                                                                                                                                                                                                                                                                                                                                                                                                                    do 60 mi=1, mmnv
                                                                                                                                                                                                                                                                                                                k = k+1
                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     = mnv
                                                                                                                                                                                                                                                                                                  else
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   000
                                                                  2020 format(5x, 'the contour levels are : ',(',10g12.4))
2020 format(5x, 'the contour levels are : ',(',10f8.2))
write(ireport,2025)
2025 format(1x)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2020) r(2),r(6),r(10),r(14),r(18),
r(22),r(26),r(30),r(34),r(38)
                                   dimension fun(max,max), fv(max), fh(max), r(39)
common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                 fun(i,j)
fun(i,j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                posx = (real(mi)/real(mmnv))*fvlen
                                                                                                                                                                         ... reset size according to scale
                                                                                                                                                                                                                                                                                                                                                                    11 11
                                                                                                                                                                                                                                                                                                                                                                   pmax
pmin
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   ... write contour levels ...
                                                                                                                                                                                                                                                                                                                                                                                                                                pstep = (pmax-pmin)/38.0
do 20 1=1, 39
  r(!) = pmin + pstep*(1-1)
                                                                                                                                                                                                                                                                                                                                                          if(fun(i,j).gt.pmax)
if(fun(i,j).lt.pmin)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              ... assign contour levels
                                                                                                                                                                                                                          0.5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ... set boundary of map
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      table(mi,mmnh) = star
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           table(mmnv,mj) = star
                                                                                                                                                                                                                                                             .. set contour levels
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            star
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         table(\tilde{1}, mj) = star
                                                                                                                                                                                                                            = scale*mnh +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 50 mi=2, mmnv-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 30 mi=1, mmnv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 40 mj=1, mmnh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            п
                                                                                                                                                                                                                                                                                                            pmin = 1.0e20
do 10 i=1, nv
do 10 j=1, nh
                                                                                                                                                                                                                                                                                            pmax = -1.0e20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        table(mi,1)
                                                                                                                                                                                                             wn.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
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*** locate minimum & maximum values of fv and positions
                                                                                                                                                                                                                                                                                                                                                                                                                                           common /fileno/inparam,irg,ireport,itin,itout
common /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
common /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                data imin,jmin,kmin,imax,jmax,kmax/0,0,0,0,0,0/
                                                                                                                                                                                                                                                                                                                                                                                     parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                           do 60 mi=1, mmnv
write(19,2030) (table(mi,mj), mj=1, mmnh)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 10 j=j,ny
  do 10 i=l,nx
  if(fv(i,j,k).lt.fvmin) then
  fvmin = fv(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if(fv(i,j,k).gt.fvmax) then
fvmax=fv(i,j,k)
                                 table(mi,mj) = chars(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 dimension fv(nxmax,nymax,nzmax)
                  if (value.le.r(k)) then
                                                                                                                                                                                                                                                                          subroutine maxmin(fv,head)
                                                                             go to 45
                                                                                                                                  ... print contour
                                                                                                                                                                                                                                                                                                                                                                                                                   character head*15
                                                           k = k+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             i = uimi
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         kmin = k
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           jmin =
                                                                                                                                                                                      2030 format(5x,128al)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          fvmin= 1.0e+20
fvmax=-1.0e+20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            kmax=k
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 imax=i
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 10 k=1,nz
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   fint1 = fun(i,j) + ratioy*(fun(i,j+1)-fun(i,j))
fint2 = fun(i+1,j) + ratioy*(fun(i+1,j+1)-fun(i+1,j))
                                                                                                                                                                                                                                                                                   format(//,5x,'the contour levels are : ',',(/,11g12.4))
write(ireport,2025)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ratiox = (posx - fv(i))/(fv(i+1)-fv(i))
ratioy = (posy - fh(j))/(fh(j+1)-fh(j))
                                                                                                                      pmax = fun(i,j)

pmin = fun(i,j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              value = fint1 + ratiox*(fint2-fint1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                posy = (real(mj)/real(mmnh))*fhlen
call search(posy, fh, j, nh)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        posx = (real(mi)/real(mmnv))*fvlen
call search(posx, fv, i, nv)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              ... assign contour levels ..
                                                                                                                                                                                                r(1) = pmin + pstep*(1-1)
                                                                                              do 10 j=1, nh
   if(fun(i,j).gt.pmax)
   if(fun(i,j).lt.pmin)
                                                                                                                                                                       pstep = (pmax-pmin)/10.0
do 20 l=1, 11
                                                                                                                                                                                                                                          · · · write contour levels
munh = scale*mnh + 0.5
                                                                                                                                                                                                                                                                                                                                          ... set boundary of map
                                                                                                                                                                                                                                                                                                                                                                                                  table(mi,mmnh) = star
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     table(mmnv,mj) = star
                             · · set contour levels
                                                                                                                                                                                                                                                                      write(ireport,2020) r
                                                                                                                                                                                                                                                                                                                                                                                         = star
                                                                                                                                                                                                                                                                                                                                                                                                                                                              = star
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 50 mj=2, mmnh-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 50 mi=2, mmnv-1
                                                                                                                                                                                                                                                                                                                                                                     do 30 mi=1, mmnv
                                                                                                                                                                                                                                                                                                                                                                                                                                          do 40 mj=1, mmnh
table(1,mj) = ;
                                                                       1.0e20
                                                         pmax = -1.0e20
                                                                               do 10 i=1, nv
                                                                                                                                                                                                                                                                                                                                                                                   table(mi,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        continue
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                                                                       = uimd
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', i3, /)
                                                                                                         prints arrays in blocks of 11 columns for y-z planes
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              u
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      if(vpform .eq. 'c') then
write(ireport,2010) head,x(ipos)
format(1h1,20x,5('*'),1x,a15,' field ',5('*'),3x,': x
f5.2,/)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  write(ireport,2011) head,ipos
format(1h1,20x,5('*'),1x,a15,' field ',5('*'),3x,': i
                                                                                                                                                                                                                                                                                                                                                                                                                                                                /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   11
                                                                                                                                                                                                                                                                                                                                                                                           common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,2020) (y(j),j=jstart,jstop)
format(//,5x,' y = ',2x,f6.3,10(5x,f6.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                .. set constants to print arrays in blocks of
                                                                                                                                                                                                                                  parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,2021) (j,j=jstart,jstop)
format(//,5x,' j = ',i4,10(7x,i4))
                                                                                                                                                                                                                                                                                                                                                                                                                             /intcom/itercmpo, norun, mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       íf(jblock*11 .ne. ny) jblock=jblock+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       common /h/hx(max),hy(max),hz(max)
                                                                                                                                                                                                                                                                                                                               character xc*1,yc*1,zc*1,vpform*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 common /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /vmpfrm/xc,yc,zc,vpform
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if(jblock.eq.kount) jstop=ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if(vpform .eq. 'c' ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        jstart=(kount-1)*11+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   dimension f(max,max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 10 kount=1,jblock
                                                                                                                                                                                                                                                                                               character*15 head
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            .. print heading
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          jstop=jstart+10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         .. print array
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          jblock=ny/11.
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      *** locate maximum value of fv and its position ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ',1pg11.4,
write(ireport,2010) head,fvmin,imin,jmin,kmin,x(imin)
                                                                                         2010 format ( /,1x, minimum value of ',a15,' is ',1pg11.4, at mesh point (',i3,',',i3,','i3,')', ie. position (x,y,z) = (', 0p,f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,'',f5.2,''
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          2010 format(//,1x,'maximum (abs) value of ',a15,' is

t mesh point (',i3,',',i3,',',i3,')',

t ' ie. position (x,y,z) = (',

t Op,f5.2,',',f5.2,',',f5.2,'))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2010) head,fvmax,ipos,jpos,kpos,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if( fvmax .lt. abs(fv(i,j,k)) )then
fvmax = abs(fv(i,j,k))
                                    + Y(jmin), z(kmin), head, fvmax, imax, jmax, kmax,
                                                                                                                                                                                                                                                                                                                            0p,f5.2,',',f5.2,',',f5.2,')')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           common /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     dimension fv(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             subroutine mprtx(f,head,ipos)
                                                                                                                                                                                                                                                                                                                                                                                                                                                          subroutine maxval(fv,head)
                                                                    x(imax),y(jmax),z(kmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     + x(ipos),y(jpos),z(kpos)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            kpos = k endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            character head*15
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     i = sodi
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 10 j=1,ny
do 10 i=1,nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    = sod
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 10 k=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    fvmax=0.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 common
                                                                                                                                                                                                                                                                                                                                                                                              return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   return
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write(ireport,2040) x(ii),(f(ii,k),k=kstart,kstop)
format(' x=',f6.3,2x,1p,11g11.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          *** prints arrays in blocks of 11 columns for x-y planes
                                                                                                                                                                                                                                                                                                                                                                                write(ireport,2041) ii,(f(ii,k),k=kstart,kstop)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                        format(//,5x,' z = ',2x,f6.3,10(5x,f6.\bar{3}))
                                                                                                                                                      write(ireport,2020) (z(k),k=kstart,kstop)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                        (k,k=kstart,kstop)
',i4,10(7x,i4))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        hxold(max),hyold(max),hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                                                              format(' i=',i3,2x,1p,11g11.3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          /h/hx(max),hy(max),hz(max),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               character xc*1,yc*1,zc*1,vpform*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /axis/x(max),y(max),z(max)
                                                                                                           if(kblock.eq.kount) kstop=nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /vmpfrm/xc,yc,zc,vpform
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   subroutine mprtz(f, head, kpos)
                                                                                                                                         if(vpform .eq. 'c' ) then
                                                                                                                                                                                                                                                                            if(vpform .eq. 'c' ) then
                                                                                                                                                                                                   write(ireport,2021)
                                                                                                                                                                                                                   format(//,5x,'k =
                                                                                kstart=(kount-1)*11+1
                                                             do 10 kount=1,kblock
                                                                                                                                                                                                                                             write(ireport,2030)
                                   .. print array ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                dimension f(max,max)
                                                                                               kstop=kstart+10
                                                                                                                                                                                                                                                                                        do 11 ii=1,nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  character*15 head
                                                                                                                                                                                                                                                                                                                                                                do 12 ii=1,nx
                                                                                                                                                                                                                                                               format(1x)
                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                continue
                                                                                                                                                                                                                                  endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                            endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                       return
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           COMMON
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,2011) head,jpos
format(1h1,20x,5('*'),1x,a15,' field ',5('*'),3x,': j = ',i3,/)
                                                                                                                                                                                                                                                                                                                   prints arrays in blocks of 11 columns for x-z planes ***
                                                           write(ireport,2040) z(kk),(f(kk,j),j=jstart,jstop)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            11
                                                                                                                                  write(ireport,2041) kk,(f(kk,j),j=jstart,jstop)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport, 2010) head, y(jpos)
format(1h1,20x,5('*'),1x,a15,' field ',5('*'),3x,': y
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   .. set constants to print arrays in blocks of
                                                                                                                                                                                                                                                                                                                                                                            parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               hxold(max),hyold(max),hzold(max)
                                                                          format(' z=',f6.3,2x,1p,11g11.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /intcom/itercmpo,norun,mainiter
                                                                                                                                                    format(' k=',i3,2x,1p,11g11.3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 nz) kblock=kblock+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /h/hx(max),hy(max),hz(max),
                                                                                                                                                                                                                                                                                                                                                                                                                       character xc*1,yc*1,zc*1,vpform*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        common /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                     /vmpfrm/xc,yc,zc,vpform
                                                                                                                                                                                                                                                     subroutine mprty(f,head,jpos)
                            if(vpform .eq. 'c' ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        then
write(ireport,2030)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if(vpform .eq. 'c' )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      dimension f(max,max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              f5.2,/)
                                          do 11 kk=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                       character*15 head
                                                                                                                    do 12 kk=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  .ne.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ... print heading
              format(1x)
                                                                                          continue
                                                                                                                                                                   continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                kblock=nz/11.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if(kblock*11
                                                                                                                                                                                               continue
                                                                                                                                                                               endif
                                                                                                                                                                                                                              return
                                                                                                                                                                                                                                                                                                                                                                                                                                                      common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    common
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           2030
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write(46,*)'Contour maps of temperature, x=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(47,*)'Contour maps of temperature, y=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(45,*) 'Velocity distribution at select points.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  open(unit=ireport ,file=filename,status='unknown')
filename=exprmnt // '.plu'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      , file=filename, status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               , file=filename, status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(iplt,*) 'Transient temperatures at select
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              ,file=filename,status='unknown')
                                                                                                                                                                                                            /logpvm/vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ,file=filename,status='unknown')
                                                                                                                                                                                        /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                  mxp1, mxp2, mxp3, mxt, mxu, mxv, mxw,
                                                                                                                                                                                                                                                    vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                             vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
                                                                                                                                                                                                                                                                                                                   mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                           vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                 vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
myp1, myp2, myp3, myt, myu, myv, myw,
                                               \mathtt{mxp1}, \mathtt{mxp2}, \mathtt{mxp3}, \mathtt{mxt}, \mathtt{mxu}, \mathtt{mxv},
                                                                                                          vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
                                                                                                                             mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(inu,*) 'Transient Nu numbers.'
     character exprmnt*8,filename*12
                                                                                                                                                                                                                                                                                                                                                      logical file numbers
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    filename=exprmnt // '.plt'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             filename=exprmnt // 'prt'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       filename=exprmnt // '.nu'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      filename=exprmnt // '.tx'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           filename=exprmnt // .ty'
open(unit=47 ,file=file
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 filename=exprmnt // 'tz'
open(unit=48 ,file=file
                                                                                                                                                    /exprmnt/exprmnt
                                                                                                                                                                     /iplt/iplt,inu
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  .. open output files
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if (mxt.or.vxt) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          if (myt.or.vyt) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if (mzt.or.vzt) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           open(unit=iplt
                                                                                                                                                                                                                                                                                                                                                                                                                                      σ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                open(unit=inu
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            open(unit=45
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                                                                                                                                                                                                                                                                                                                                                                                                                                                        tin = 11
                           logical
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     close(46)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           close(47)
                                                                                                                                                                                                                                                                                                                                                                                                                     н
                                                                                                                                                                                                                                                                                                                                                                                                                                      report
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                                                                                                                                                                                                                                                                                                                                                                                             lnu=31
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                                                                                                                                          = ', i3, /)
                                                              п
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport,2040) x(ii),(f(ii,j),j=jstart,jstop)
format(' x=',f6.3,2x,1p,11g11.3)
                                                                                                   write(ireport,2011) head,kpos
format(1h1,20x,5('*'),1x,a15,' field ',5('*'),3x,': k
                                        format(lh1,20x,5('*'),1x,a15,' field ',5('*'),3x,': z
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport,2041) ii,(f(ii,j),j=jstart,jstop)
                                                                                                                                                                                                   of 11
                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(ireport,2020) (y(j),j=jstart,jstop) format(//,5x,' y = ',2x,f6.3,10(5x,f6.3)
                                                                                                                                                                                        ... set constants to print arrays in blocks
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(ireport,2021) (j,j=jstart,jstop)
format(//,5x,' j = ',i4,10(7x,i4))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      creating output files
                                                                                                                                                                                                                                                      ny) jblock=jblock+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    format(' i=',i3,2x,1p,11g11.3)
                            head, z(kpos)
                                                                                                                                                                                                                                                                                                                                                                                            if (jblock.eq.kount) jstop=ny
                                                                                                                                                                                                                                                                                                                                                                                                                                    if(vpform .eq. 'c' ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       if(vpform .eq. 'c' ) then
if(vpform .eq. 'c' ) then
write(ireport,2010) head
                                                                                                                                                                                                                                                                                                                                                      jstart=(kount-1)*11+1
                                                                 f5.2,/)
                                                                                                                                                                                                                                                                                                                                do 10 kount=1,jblock
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,2030)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   subroutine outfiles
                                                                                                                                                                                                                                                 if(jblock*11 .ne.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 11 ii=1,nx
                                                                                                                                                                                                                                                                                                                                                                            |stop=jstart+10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 12 ii=1,nx
                                                                                                                                                                                                                                                                                          .. print array
                                                                                                                                                                                                                              jblock=ny/11.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      format(1x)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            endi f
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                                                                                      else
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write(48,*)'Contour maps of temperature, z=constant planes.
                                                                                                                                                                                                                                                                                                                                                                                                     filename=exprmnt // .uzd'
open(unit=51 ,file=filename,status='unknown')
write(51,*)'Contour maps of x component velocity, u,
                                                                                                                              write(49,*)'Contour maps of x component velocity, u,
                                                                                                                                                                                                                                                                                         write(50,*)'Contour maps of x component velocity, u,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        write(52,*)'Contour maps of y component velocity, v,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(53,*)'Contour maps of y component velocity,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 write(54,*)'Contour maps of y component velocity,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    open(unit=55 ,file=filename,status='unknown')
write(55,*)'Contour maps of z component velocity,
                                                                                                              , file=filename, status='unknown')
                                                                                                                                                                                                                                            filename=exprmnt // .uyd'
open(unit=50 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        filename=exprmnt // ..vxd'
open(unit=52 , file=filename, status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                filename=exprmnt // '.vyd'
open(unit=53 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 filename=exprmnt // '.vzd'
open(unit=54 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            , file=filename, status='unknown')
                                                                                    filename=exprmnt // '.uxd'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              filename=exprmnt // '.wxd'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    filename=exprmnt // '.wyd'
                                                                                                                                                        'x=constant planes.'
                                                                  if (mxu.or.vxu) then
                                                                                                                                                                                                                        if (myu.or.vyu) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (mxv.or.vxv) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                (myv.or.vyv) then
                                                                                                                                                                                                                                                                                                                                                                                   if (mzu.or.vzu) then
                                                                                                                                                                                                                                                                                                                  'Y=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 'x=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      (mzv.or.vzv) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                       + 'z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  'Y=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (mxw.or.vxw) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           'z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    (myw.or.vyw) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                'x=constant planes.'
                                                                                                                 open(unit=49
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              open(unit=56
                                                                                                                                                                              close(49)
                                                                                                                                                                                                                                                                                                                                        close(50)
                       close(48)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 close(51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      close(52)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          close(53)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               close(54)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        close (55)
                                                                                                                                                                                                        endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              endi f
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open(unit=58 ,file=filename,status='unknown')
write(58,*)'Contour maps of square root of (v*v+w*w),
                                                                                                                                                                                                                                                                                                                                                                                                   filename=exprant // '.uwy'
open(unit=59 ,file=filename,status='unknown')
write(59,*)'Contour maps of square root of (u*u+w*w),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(60,*)'Contour maps of square root of (u*u+v*v),
                                                                                                                                 write(57,*)'Contour maps of z component velocity, w,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(61,*)'Contour maps of pl, x=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(62,*)'Contour maps of pl, y=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  write(63,*)'Contour maps of pl, z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               open(unit=64 ,file=filename,status='unknown')
write(64,*)'Contour maps of p2, x=constant planes.'
                                                                                     filename=exprmnt // '.wzd'
open(unit=57 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     , file=filename, status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        open(unit=62 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ,file=filename,status='unknown')
                                                                                                                                                                                                                                               filename=exprmnt // '.vwx'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             filename=exprmnt // '.uvz'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 filename=exprmnt // '.plx'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   filename=exprmnt // .ply
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     filename=exprmnt // '.plz'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       filename=exprmnt // 'p2x'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               (mxpl.or.vxpl) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (mypl.or.vypl) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (mzpl.or.vzpl) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if (mxp2.or.vxp2) then
                                                                if (mzw.or.vzw) then
'y=constant planes.'
                                                                                                                                                                                                                            if (mxu.or.vxu) then
                                                                                                                                                                                                                                                                                                                                                                                  if (myv.or.vyv) then
                                                                                                                                                        + 'z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           (mzw.or.vzw) then
                                                                                                                                                                                                                                                                                                                + 'x=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           'y=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  + 'z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       open(unit=60
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             open(unit=61
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               open(unit=63
                        close(56)
                                                                                                                                                                                close(57)
                                                                                                                                                                                                                                                                                                                                          close(58)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                close(59)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        close(60)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        close(61)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            close(63)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          close(62)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             close(64)
                                                                                                                                                                                                        endif
                                                                                                                                                                                                                                                                                                                                                                endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          endi f
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write(56,*)'Contour maps of z component velocity,

logical

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0 0 0 0 0 0 0

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common /reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,ccp,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos
                                                                                                                                                                                                                                                                                                                             /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(33,*)'Transient t distribution along x axis.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /horitemp/horitemp(3,20,41),horiu(3,20,41),
horiv(3,20,41),horiw(3,20,41)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                        common /fileno/inparam,irg,ireport,itin,itout
common /logc/reed,rite,strt,dist,heat,nuss,tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /vmppos/rmx(nxmax),rmy(nymax),rmz(nzmax)
                                                                                                                                        common /logpvm/vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /epsonnu/epson,xll,annu,gravity,ddd,keff
/ccaa/cc0,dtemp,tcold,thot
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               , file=filename, status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   , file=filename, status='unknown')
                                                                                                                                                                 mxpl,mxp2,mxp3,mxt,mxu,mxv,mxw,
vypl,vyp2,vyp3,vyt,vyu,vyv,vyw,
myp1,myp2,myp3,myt,myu,myv,myw,
                                                                                                                                                                                                                                     vzp1,vzp2,vzp3,vzt,vzu,vzv,vzw,
mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   horiu(i,j,k)=1000.*horiu(i,j,k)*alphap/x11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          horiv(i,j,k)=1000.*horiv(i,j,k)*alphap/xll
horiw(i,j,k)*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    /vmploc/mx(nxmax), my(nymax), mz(nzmax)
                                                                                                                                                                                                                                                                                                                                                                           hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                          cct, tmax, pdist, rtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /t/theta(nxmax,nymax,nzmax)
                                            character xc*1,yc*1,zc*1,vpform*1
                                                                                                                                                                                                                                                                                                                                                    /h/hx(max), hy(max), hz(max)
                                                                                                                                                                                                                                                                                                                                                                                               /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /p1/p1(nxmax,nymax,nzmax)
character exprmnt*8, filename*12
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        w(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                          /vmpfrm/xc,yc,zc,vpform
                                                                                                                                                                                                                                                                                                                                                                                                                                               /vmpnum/npx,npy,npz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                /mapcom/mnx,mny,mnz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    filename=exprmnt // '.txt'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /realtime/realtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          filename=exprmnt // '.xu'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          /exprmnt/exprmnt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /finish/finish
                       character*25 head
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 7005 k=1,41
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if (finish) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             7005 i=1,3
7005 j=1,20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   open(unit=36
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               open(unit=33
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                                                                     O
                                                                         write(65,*)'Contour maps of p2, y=constant planes.'
                                                                                                                                                                                                               write(66,*)'Contour maps of p2, z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 write(68,*)'Contour maps of p3, y=constant planes.'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(69,*)'Contour maps of p3, z=constant planes.'
                                                                                                                                                                                                                                                                                                                                                        write(67,*)'Contour maps of p3, x=constant planes.
                                                                                                                                                                 filename=exprmnt // '.p2z'
open(unit=66 ,file=filename,status='unknown')
                                                  ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                   filename=exprmnt // '.p3y'
open(unit=68 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                     ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   open(unit=69 ,file=filename,status='unknown')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 * * *
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 БЗ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     logical reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 p2,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              vxp1, vxp2, vxp3, vxt, vxu, vxv, vxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       mxp1, mxp2, mxp3, mxt, mxu, mxv, mxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         vypl, vyp2, vyp3, vyt, vyu, vyv, vyw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                myp1,myp2,myp3,myt,myu,myv,myw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       vzp1,vzp2,vzp3,vzt,vzu,vzv,vzw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              mzp1,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 w, pl,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 n, v
                          filename=exprmnt // '.p2y'
                                                                                                                                                                                                                                                                                                            filename=exprmnt // '.p3x'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           filename=exprmnt // '.p3z'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       *** prints theta,
     if (myp2.or.vyp2) then
                                                                                                                                              if (mzp2.or.vzp2) then
                                                                                                                                                                                                                                                                                     (mxp3.or.vxp3) then
                                                                                                                                                                                                                                                                                                                                                                                                                              (myp3.or.vyp3) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      (mzp3.or.vzp3) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               subroutine output
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ogical finish
                                                     open(unit=65
                                                                                                                                                                                                                                                                                                                                       open(unit=67
                                                                                                  close(65)
                                                                                                                                                                                                                                            close(66)
                                                                                                                                                                                                                                                                                                                                                                                   close (67)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            close(68)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   close(69)
```

return

endi f

endif

endif

endi f

| + 30 | <pre>write(41,*)'y axis, w mm/s velocity distribution.' write(41,*)'at: <1 1 5 10 15 + 30 40 50 60 80 hours' pstion=0. do 7001 i=1,ny</pre> | | <pre>write(41,8001) pstion, (horiw(2,n,i),n=1,20) pstion=pstion+hy(i) 7001 continue close(34) close(39) close(40) close(40)</pre> | fil fil fil fil fil fil fil | <pre>filename=exprmnt // '.zw' open(unit=44 ,file=filename,status='unknown') write(44,*)'Transient w distribution along z axis.' write(35,*)'at: <1 1 5 10 15 20 + 30 40 50 60 80 hours'</pre> | <pre>write(42,*)'z axis, u mm/s velocity distribution.' write(42,*)'at: <1 1 5 10 15 20 * 30</pre> |
|---|---|--|---|---|---|--|
| 50 | 20 | 20 | | | | 20 |
| <pre>write(36,*)'Transient u distribution along x axis.' filename=exprmnt // .xv' open(unit=37 ,file=filename,status='unknown') write(37,*)'Transient v distribution along x axis.' open(unit=38 ,file=filename,status='unknown') write(38,*)'Transient w distribution along x axis.' write(38,*)'at: <1</pre> | <pre>write(36,*)'x axis, u mm/s velocity distribution.' write(36,*)'at: <1 1 5 10 15 10 15 1 30 40 50 80 hours' write(37,*)'x axis, v mm/s velocity distribution.' write(37,*)'at: ', ', 'mm/s velocity distribution.'</pre> | write(38,*)'at: <1 1 5 10 15 write(38,*)'x axis, w mm/s velocity distribution.' write(38,*)'at: <1 1 5 10 15 30 40 50 60 80 hours' | <pre>pstion=0. do 7000 i=1,nx write(33,8002) pstion, (horitemp(1,n,i),n=1,20) write(36,8001) pstion, (horiu(1,n,i), n=1,20)</pre> | <pre>write(37,8001) pstion, (horiv(1,n,i), n=1,20) write(38,8001) pstion, (horiw(1,n,i), n=1,20) pstion=pstion+hx(i) continue close(33) close(33) close(36) close(37) close(37)</pre> | <pre>filename=exprmnt // '.tyt' open(unit=34 ,file=filename,status='unknown') write(34,*)'Transient t distribution along y axis.' filename=exprmnt // '.yu' open(unit=39 ,file=filename,status='unknown') write(39,*)'Transient u distribution along y axis.' filename=exprmnt // '.vv'</pre> | <pre>open(unit=40</pre> |

```
,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ,file=filename,status='old',access='append')
                                                                                                                                                              aux2d(k,j) = theta(mx(i),j,k)*dtemp+tcold
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       aux2d(k,j) =u(mx(i),j,k)*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(ireport,*)'realtime=',realtime
write(ireport,2010) head,mx(i),x(mx(i))
                                                                         if ((ireport .eq. 46).and.(vxt.or.mxt)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                   if ((ireport .eq. 49).and.(vxu.or.mxu)) then
filename=exprmnt // '.uxd'
open(unit=49 , file=filename,status='old',ac')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      .eq. 58).and.(vxu.or.mxu)) then
                                                                                                                                                                                                                     if (vxt) call mprtx(aux2d,head,mx(i))
if (mxt) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (vxu) call mprtx(aux2d,head,mx(i))
if (mxu) then
                                                                                                                                                                                                           temperature degree c'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   u-velocity mm/s
                                                                                       filename=exprmnt // '.tx'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 filename=exprmnt // '.vwx'
                                                                                                                                                                                                                                                   write(ireport,*)
                                                                                                                  do 11 i=1, npx
do 10 k=1, nz
do 10 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 21 i=1, npx
do 20 k=1, nz
do 20 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          .. v and w velocity
                if (npx.gt.0) then
                                                 .. temperature
                                                                                                                                                                                                                                                                                                                                                                                                             .. u-velocity
                                                                                                       open(unit=46
                                                                                                                                                                                                          head = '
                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if ((ireport
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     head = '
                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                 close(46)
                                                                                                                                                                                                                                                                                                                                     endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                close (49)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
                                                                                                                                                                                                                                                                                                                                                                               endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               endi f
                                                                                                                                                                            10
                                                                                                                                                                                                                                                                                          2010
                                                                                                                                                                                                                                                                                                                                                  11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                21
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                                                                                                                                                                                                                                                                                                                                                                                             000
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             O
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       OO
                                                                                                                                                                                                                                                                                                                                  20
                                                                                                                                                                                                                                                                                                                                                                      t(mx,iy,mz)
write(44,*)'z axis, w mm/s velocity distribution.
                                   80 hours'
                                                                                       pstion, (horitemp(3,n,i),n=1,20)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ... print variables in y-z planes (x=constant)
                                                                                                               write(42,8001) pstion, (horiu(3,n,i),n=1,20)
                                                                                                                                           write(43,8001) pstion, (horiv(3,n,i),n=1,20)
                                                                                                                                                                       write(44,8001) pstion,(horiw(3,n,i),n=1,20)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(32,8000) xpstion,theta(i,mmy,mmz),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   format(1x,3(f7.4,1x,f10.6,2x))
                                   09
                                                                                                                                                                                                                 format(1x, f5.3,20(1x, f8.3))
format(1x, f5.3,20(1x, f8.6))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ypstion, theta(mmx,i,mmz),
zpstion, theta(mmx,mmy,i)
                                                                                                                                                                                                                                                                                                                  filename=exprmnt // '.dis'
                                                                                                                                                                                                                                                                                                                                                                                                                                               if ( mm .lt. ny) mm=ny
if ( mm .lt. nz) mm=nz
                   7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            xpstion=xpstion+hx(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          ypstion=ypstion+hy(i)
                                                                                                                                                                                                                                                                                                                                                                              t (mx, my, iz) '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         zpstion=zpstion+hz(i)
                                                                                                                                                                                       pstion=pstion+hz(i)
              write(44,*)'at:
                                                                                    write(35,8002)
                                                      do 7002 i=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 1000 i=1,mm
                              40
                                                                                                                                                                                                                                                                                                                                                                                        mmx = (nx+1)/2
                                                                                                                                                                                                                                                                                                                                                                                                        mmy = (ny+1)/2
mmz = (nz+1)/2
                                         pstion =0.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                             xpstion=0.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             ypstion=0.
                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                              close (35)
                                                                                                                                                                                                                                                           close(42)
                                                                                                                                                                                                                                                                           close (43)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          zpstion=0
                                                                                                                                                                                                                                                                                          close(44)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    close(32)
                                                                                                                                                                                                                                                                                                                                                                                                                                    xu=ww
                                                                                                                                                                                                    7002
8001
8002
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     1000
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                8000
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, file=filename, status='old', access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ,file=filename,status='old',access='append')
                                                                                    write(ireport,*)'realtime=',realtime
write(ireport,2010) head,mx(i),x(mx(i))
call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,*)'realtime=',realtime
write(ireport,2010) head,mx(i),x(mx(i))
call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                                                                                                                                                                                              if ((ireport .eq. 61).and.(vxpl.or.mxpl)) then filename=exprmnt // '.plx'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,*)'realtime=',realtime
write(ireport,2010) head,mx(i),x(mx(i))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if ((ireport .eq. 64).and.(vxp2.or.mxp2)) then
                                  if (vxw) call mprtx(aux2d,head,mx(i))
if (mxw) then
                                                                                                                                                                                                                                                                                                                                                                                                                                        if (vxp1) call mprtx(aux2d,head,mx(i))
if (mxp1) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              if (vxp2) call mprtx(aux2d,head,mx(i))
if (mxp2) then
                                                                                                                                                                                                                                                                                                              do 51 i=1, npx
do 50 k=1, nz
do 50 j=1, ny
aux2d(k,j) = p1(mx(i),j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            aux2d(k,j) = p2(mx(i),j,k)
                    w-velocity mm/s
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    filename=exprmnt // .p2x
                                                                     write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                            psi-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    psi-2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 61 i=1, npx
do 60 k=1, nz
do 60 j=1,
                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                    open(unit=61
                                                                                                                                                                                                                                                                                                                                                                                                                          head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         open(unit=64
                  head =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               head = '
                                                                                                                                                             continue
                                                                                                                                                                             close (52)
                                                                                                                                                                                                                               .. psi-1
                                                                                                                                          endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  close(61)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    .. psi-2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
                                                                                                                                                                                              endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  endi f
                                                                                                                                                          41
                                                                                                                                                                                                                                                                                                                                                                                     50
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      61
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,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                           ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 v(mx(i),j,k)*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 41 i=1, npx
do 40 k=1, nz
do 40 j=1, ny
aux2d(k,j) = w(mx(i),j,k)*1000.*alphap/xll
                                                                       v(mx(i),j,k)*v(mx(i),j,k)+
                                                                                                                                                                                                                                                                 call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                               aux2d(k,j) = v(mx(i),j,k)* v(mx(i),j,k
w(mx(i),j,k)
aux2d(k,j) = sqrt(aux2d(k,j) )*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                                                                                                                                                                             write(ireport,2010) head,mx(i),x(mx(i))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 write(ireport,*)'realtime=',realtime
write(ireport,2010) head,mx(i),x(mx(i))
                                                                                                                                                                                                                                                                                                                                                                                                    if ((ireport .eq. 52).and.(vxv.or.mxv)) then
filename=exprmnt // '.vxd'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if ((ireport .eq. 55).and.(vxw.or.mxw)) then
filename=exprmnt // '.wxd'
open(unit=55 , file=filename,status='old',ac
                                                                                                                                                                                                                              write(ireport,*)'realtime=',realtime
                                                                                                                                                                           if (vxu) call mprtx(aux2d,head,mx(i))
if (mxu) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (vxv) call mprtx(aux2d,head,mx(i))
                                                                                                                                                       head = 'v & w-velocity mm/s'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  v-velocity mm/s'
                                                                                                                                                                                                             write(ireport,*)
                          do 530 k=1, nz
do 530 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               aux2d(k,j) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 31 i=1, npx
do 30 k=1, nz
do 30 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (mxv) then
           do 531 i=1, npx
                                                                                                                                                                                                                                                                                                                                                                       .. v-velocity
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              .. w-velocity
                                                                                                                                                                                                                                                                                                                                                                                                                                        open(unit=52
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  head = '
                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                 endif
                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         close(52)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        endî f
                                                                                                                                                                                                                                                                                                                    close(58)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           endi f
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                                                                                     +
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              30
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                                                                                                                     530
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open(unit=58

531

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,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if ((ireport .eq. 59).and.(vyv.or.myv)) then
filename=exprmnt // '.uwy'
open(unit=59 ,file=filename,status='old',access='append')
                                                                                                                                                                                                                u(i,my(j),k)*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 231 j=1, npy
do 230 i=1, nx
do 230 k=1, nz
aux2d(i,k) = v(i,my(j),k)*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                   write(ireport,*)'realtime=',realtime
write(ireport,2020) head,my(j),y(my(j))
call map(aux2d,x,z,nx,nz,mnx,mnz,arz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,*)'realtime=',realtime
write(ireport,2020) head,my(j),y(my(j))
call map(aux2d,x,z,nx,nz,mnx,mnz,arx,arz)
                                                                                                     if ((ireport .eq. 50).and.(vyu.or.myu)) then
filename=exprmnt // '.uyd'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if ((ireport .eq. 53).and.(vyv.or.myv)) then
                                                                                                                                                                                                                                                                                   if (vyu) call mprty(aux2d,head,my(j))
if (myu) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      if (vyv) call mprty(aux2d,head,my(j))
if (myv) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         v-velocity mm/s '
                                                                                                                                                                                                                                                                      u-velocity mm/s
                                                                                                                                                                                                                   Н
                                                                                                                                                                                                                                                                                                                    write(ireport,*)
                                                                                                                                                                                                   2
U
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(ireport,*)
                                                                                                                                                         do 221 j=1, npy
do 220 i=1, nx
do 220 k=1, n
aux2d(i,k) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .. u and w -velocity
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              filename=exprmnt //
open(unit=53 ,file
                                                                        .. u-velocity
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 631 j=1, npy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                              .. v-velocity
                                                                                                                                           open(unit=50
                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                   head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         head = '
                  close(47)
                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                             close(50)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                                                                                                                                                                                                                                                                                                                                                                                          endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                close(53)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             endi f
                                       endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                           endi f
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                                                                                                                                                                                                                               220
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,*)'realtime=',realtime
write(ireport,2020) head,my(j),y(my(j))
format(lh1,10x,5('*'), contour map of ',a15,5('*'),3x,
call map(aux2d,x,z,nx,nz,mnx,mnz,arx,arz)
                                                                                                                           , file=filename, status='old', access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            theta(i, my(j), k) *dtemp+tcold
                                                                                                                                                                                                                                                                                                                                                       call map(aux2d,z,y,nz,ny,mnz,mny,arz,ary)
                                                                                  if ((ireport .eq. 67).and.(vxp3.or.mxp3)) then
filename=exprmnt // '.p3x'
                                                                                                                                                                                                                                                                                                                   write(ireport,*)'realtime=',realtime
write(ireport,2010) head,mx(i),x(mx(i))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              .. print variables in x-z planes (y=constant)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if ((ireport .eq. 47).and.(vyt.or.myt)) then
filename=exprmnt // '.ty'
                                                                                                                                                                                                                                                                if (vxp3) call mprtx(aux2d,head,mx(i))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if (vyt) call mprty(aux2d, head, my(j))
if (myt) then
                                                                                                                                  do 71 i=1, npx

do 70 k=1, nz

do 70 j=1, ny

aux2d(k,j) = p3(mx(i),j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            head = ' temperature degree c'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   open(unit=47 , file=file
do 211 j=1, npy
do 210 i=1, nx
do 210 k=1, nz
aux2d(i,k) = t
                                                                                                                                                                                                                                                                                                 write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,*)
                                                                                                                                                                                                                                                     psi-3
                                                                                                                                                                                                                                                                               if (mxp3) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              if (npy.gt.0) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  .. temperature
                                                                                                                        open(unit=67
                                                                                                                                                                                                                                                head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
close (64)
                                                  .. psi-3
                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                       endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                        close(67)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
               endif
                                                                                                                                                                                                                                                                                                                                                                                                                                           endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                              endif
                                                                                                                                                                                                            70
                                                                                                                                                                                                                                                                                                                                                                                      71
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          210
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2020
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     211
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υU O

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, file=filename, status='old', access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ,file=filename,status='old',access='append')
                                                                                          call map(aux2d,x,z,nx,nz,mnx,mnz,arx,arz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                        call map(aux2d,x,z,nx,nz,mnx,mnz,arx,arz)
                                                                         write(ireport,2020) head,my(j),y(my(j))
                                                                                                                                                                                                                      if ((ireport .eq. 65).and.(vyp2.or.myp2)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 call map(aux2d,x,z,nx,nz,mnx,mnz,arz)
                                                                                                                                                                                                                                                                                                                                                                                                                                      write(ireport,*)'realtime=',realtime
write(ireport,2020) head,my(j),y(my(j))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if ((ireport .eq. 68).and.(vyp3.or.myp3)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              write(ireport, 2020) head, my(j), y(my(j))
                                                           write(ireport,*)'realtime=',realtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,*)'realtime=',realtime
                                                                                                                                                                                                                                                                                                                                                                                        if (vyp2) call mprty(aux2d,head,my(j))
if (myp2) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if (vyp3) call mprty(aux2d,head,my(j))
                                                                                                                                                                                                                                                                                                                        aux2d(i,k) = p2(i,my(j),k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 271 j=1, npy
do 270 i=1, nx
do 270 k=1, nz
aux2d(i,k) = p3(i,my(j),k)
                                                                                                                                                                                                                                      filename=exprmnt // '.p2y'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    filename=exprmnt // '.p3y'
                                          write(ireport,*)
                                                                                                                                                                                                                                                                                   do 260 i=1, nx
do 260 k=1, nz
                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                             psi-2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       psi-3
                        if (myp1) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if (myp3) then
                                                                                                                                                                                                                                                                      do 261 j=1, npy
                                                                                                                                                                                                                                                        open(unit=65
                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                         head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       open(unit=68
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   head = '
                                                                                                                           continue
                                                                                                                                           close(62)
                                                                                                                                                                                          .. psi-2
                                                                                                         endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       close(65)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       .. psi-3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   endi f
                                                                                                                                                         endi £
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   endi f
                                                                                                                       251
                                                                                                                                                                                                                                                                                                                                     260
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    261
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 270
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                271
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                                                                                                                                                                                                                                                                                                                                                        O
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  O
                                                                                                                                                                                                                                                                                                                                                                                      ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                do 241 j=1, npy
do 240 i=1, nx
do 240 k=1, nz
aux2d(i,k) = w(i,my(j),k)*1000.*alphap/xll
                                   aux2d(i,k) = u(i,my(j),k)* u(i,my(j),k)*
                                                                                                                                                                                    write(ireport,*)'realtime=',realtime
write(ireport,2020) head,my(j),y(my(j))
call map(aux2d,x,z,nx,nz,mnx,mnz,arx,arz)
                                                                  aux2d(i,k) = sqrt(aux2d(i,k))*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  call map(aux2d,x,z,nx,nz,mnx,mnz,arz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,*)'realtime=',realtime
write(ireport,2020) head,my(j),y(my(j))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if ((ireport .eq. 62).and.(vypl.or.mypl)) then
                                                                                                                                                                                                                                                                                                                                                  if ((ireport .eq. 56).and.(vyw.or.myw)) then
filename=exprmnt // '.wyd'
                                                                                                                                   if (vyv) call mprty(aux2d, head, my(j))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if (vyw) call mprty(aux2d,head,my(j))
if (myw) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (vyp1) call mprty(aux2d,head,my(j))
                                                                                                                              umu∕s,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 aux2d(i,k) = p1(i,my(j),k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            mm/s
                                                                                                                   head = 'u & w velocity
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      w-velocity
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              filename=exprmnt // '.ply'
                                                + w(i,my(j),k)*w(i,my(j),k)
                                                                                                                                                                    write(ireport,*)
do 630 i=1, nx
do 630 k=1, nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 250 i=1, nx
do 250 k=1, nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   psi-1
                                                                                                                                                  if (myv) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 251 j=1, npy
                                                                                                                                                                                                                                                                                                                      .. w-velocity
                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    head = '
                                                                                                                                                                                                                                                                                                                                                                                      open(unit=56
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  open(unit=62
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                head = '
                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                      close(59)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  close(56)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .. psi-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  endi f
                                                                                                                                                                                                                                                                                      endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  endi f
                                                                                  630
                                                                                                                                                                                                                                                    631
                                                                                                                                                                                                                                                                                                                                                                                                                                                                  240
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 241
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              250
```

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open(unit=54 ,file=filename,status='old',access='append')
do 431 k=1, npz
                                                                                                                                                                                                                                                                                                                                                                                                                                                             , file=filename, status='old', access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                       open(unit=57 , file=filename, status='old', access= apd 441 k=1, npz do 440 i=1, nx do 440 j=1, ny aux2d(i,j) = w(i,j,mz(k))*1000.*alphap/xll
                                                                                                                                              v(i,j,mz(k))*1000.*alphap/xll
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              u(i,j,mz(k)) * u(i,j,mz(k))+
                                                                                                                                                                                                                                                                                               call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                           write(ireport,*)
write(ireport,*)'realtime=',realtime
write(ireport,2030) head,mz(k),z(mz(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(ireport,2030) head,mz(k),z(mz(k))
                                          if ((ireport .eq. 54).and.(vzv.or.mzv)) then
filename=exprmnt // '.vzd'
                                                                                                                                                                                                                                                                                                                                                                                                                           if ((ireport .eq. 57).and.(vzw.or.mzw)) then
filename=exprmnt // '.wzd'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          if ((ireport .eq. 60).and.(vzw.or.mzw)) then
filename=exprmnt // '.uvz'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,*)'realtime=',realtime
                                                                                                                                                                                          if (vzv) call mprtz(aux2d,head,mz(k))
if (mzv) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (vzw) call mprtz(aux2d,head,mz(k))
if (mzw) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             w-velocity mm/s'
                                                                                                        do 430 i=1, nx
do 430 j=1, ny
aux2d(i,j) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 741 k=1, npz
do 740 i=1, nx
do 740 j=1, ry
aux2d(i,j) = 1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             .. u and v -velocity
             v-velocity
                                                                                                                                                                                                                                                                                                                                                                                               .. w-velocity
                                                                                                                                                                continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           open(unit=60
                                                                                                                                                                                                                                                                                                                                continue
                                                                                                                                                                                                                                                                                                                                              close(54)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             close(57)
                                                                                                                                                                                                                                                                                                                endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              endi f
                                                                                                                                                                                                                                                                                                                                                              endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              endi f
                                                                                                                                                              430
                                                                                                                                                                                                                                                                                                                             431
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              440
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             441
               O O
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               \circ \circ \circ
                                                                                                                                                                                                                                                                                                                                                  , file=filename, status='old', access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   , file=filename, status='old', access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            open(unit=51 , file=filename, status= olu ,ucccccd do 421 k=1, npz do 420 i=1, nx do 420 j=1, ny aux2d(i,j) = u(i,j,mz(k))*1000.*alphap/xll
                                                                                                                                                                                                                                                      theta(i,j,mz(k))*dtemp+tcold
                                                                                                                                                                                                                                                                                                                                                                                                                                 call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                write(ireport,*)'realtime=',realtime
write(ireport,2030) head,mz(k),z(mz(k))
                                                                                                                                               if ((ireport .eq. 48).and.(vzt.or.mzt)) then
filename=exprmnt // '.tz'
                                               ... print variables in x-y planes (z=constant)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if ((ireport .eq. 51).and.(vzu.or.mzu)) then
filename=exprmnt // '.uzd'
                                                                                                                                                                                                                                                                                                   head = ' temperature degree c'
if (vzt) call mprtz(aux2d,head,mz(k))
if (mzt) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   if (vzu) call mprtz(aux2d,head,mz(k))
if (mzu) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    u-velocity mm/s'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  write(ireport,*)
                                                                                                                                                                                                              do 410 i=1, nx
do 410 j=1, ny
aux2d(i,j) =
                                                                               if (npz.gt.0) then
                                                                                                                                                                              open(unit=48
do 411 k=1, npz
                                                                                                                     .. temperature
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      .. u-velocity
                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 close(48)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
close(68)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     close(51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    endi f
             endif
                                                                                                                                                                                                                                                                                                                                                                                                  2030
                                                                                                                                                                                                                                                                   410
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    411
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 420
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  O
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solve for new x-component vector potential in porous ***
                                                                                                                                                                                                                ,file=filename,status='old',access='append')
                                         call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                    call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                        write(ireport,2030) head,mz(k),z(mz(k))
                                                                                                                                                                                    69).and.(vzp3.or.mzp3)) then
                                                                                                                                                                                                                                                                                                                                                                                                   write(ireport,2030) head,mz(k),z(mz(k))
                                                                                                                                                                                                                                                                                                                                                                                      write(ireport,*)'realtime=',realtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                        if (vzp3) call mprtz(aux2d,head,mz(k))
if (mzp3) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common /h/hx(max),hy(max),hz(max),
hxold(max),hyold(max),hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                a(max), b(max), c(max), d(max)
                                                                                                                                                                                                                                         do 470 i=1, nx
do 470 j=1, ny
aux2d(i,j) = p3(i,j,mz(k))
                                                                                                                                                                                              filename=exprmnt // '.p3z'
                                                                                                                                                                                                                                                                                                                                                                      write(ireport,*)
                                                                                                                                                                                                                                                                                                                            psi-3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            common /alpfs/alpp,altp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            common /phierr/phierr
                                                                                                                                                                             if ((ireport .eq.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        common /pconsp/cpp1
                                                                                                                                                                                                                             do 471 k=1, npz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        subroutine plsolp
                                                                                                                                                                                                                open(unit=69
                                                                                                                                                                                                                                                                                                                            head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              common /dt/dt
                                                                        continue
                                                                                                                                                  .. psi-3
                                                                                      close(66)
                                                       endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                   close(69)
                                                                                                                                                                                                                                                                                                                                                                                                                                    endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               dimension
                                                                                                     endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      * * *
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            end
                                                                   461
                                                                                                                                                                                                                                                                                         470
                                                                                                                                                                                                                                                                                                                                                                                                                                                 471
                                                                                                                                   000
                                                                                                                                                                                                                                                                                                          O
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     \circ \circ \circ \circ \circ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 U
                                                                                                                                                                                                                                                                                                                       ,file=filename,status='old',access='append')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ,file=filename,status='old',access='append')
                  aux2d(i,j) = sqrt(aux2d(i,j))*1000.*alphap/xll
                                                                                                                                                            call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         call map(aux2d,x,y,nx,ny,mnx,mny,arx,ary)
                                                                                                                            write(ireport,*)'realtime=',realtime
write(ireport,2030) head,mz(k),z(mz(k))
                                                                                                                                                                                                                                                                                    if ((ireport .eq. 63).and.(vzpl.or.mzpl)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,*)'realtime=',realtime
write(ireport,2030) head,mz(k),z(mz(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if ((ireport .eq. 66).and.(vzp2.or.mzp2)) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(ireport,*)'realtime=',realtime
                                                                           if (vzw) call mprtz(aux2d,head,mz(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                              if (vzp1) call mprtz(aux2d,head,mz(k))
if (mzp1) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (vzp2) call mprtz(aux2d,head,mz(k))
                                                                                                                                                                                                                                                                                                                                               do 450 i=1, nx
do 450 j=1, ny
aux2d(i,j) = p1(i,j,mz(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 460 i=1, nx
do 460 j=1, ny
aux2d(i,j) = p2(i,j,mz(k))
                                                                         mm/s,
                                                               head = 'u & v velocity
v(i,j,mz(k))*v(i,j,mz(k))
                                                                                                                                                                                                                                                                                                     filename=exprmnt // '.pl2'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       '. p2z'
                                                                                                               write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(ireport,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                    psi-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             psi-2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                filename=exprmnt //
                                                                                            if (mzw) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       if (mzp2) then
                                                                                                                                                                                                                                                                                                                                  do 451 k=1, npz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 461 k=1, npz
                                   continue
                                                                                                                                                                                                                                                                                                                    open(unit=63
                                                                                                                                                                                                                                                                                                                                                                                                                                 head = '
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 open(unit=66
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            head = '
                                                                                                                                                                                             continue
                                                                                                                                                                                                            close(60)
                                                                                                                                                                                                                                                          .. psi-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     .. psi-2
                                                                                                                                                                            endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        close(63)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        endi f
                                                                                                                                                                                                                         endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      endi f
                            740
                                                                                                                                                                                         741
                                                                                                                                                                                                                                                                                                                                                                                               450
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      451
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           460
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darcy1*(p1(nx,j,k-1)*cz4(k)+p1(nx,j,k+1)*cz6(k))
                                                                                                                                                                                                                                       + p1(nx,j,k)*(cx5h + cy5(j) + darcy1*cz5(k))
                                                                                                                                                                                                                                                    pl(nx,j-1,k)*cy4(j) + pl(nx,j+1,k)*cy6(j)
                                      cxm1zm1(j,k)*p3(i,j-1,k-1)+cxzm1(j,k)*p3(i,j,k-1)+
cxp1zm1(j,k)*p3(i,j+1,k-1)+cxm1z(j,k)*p3(i,j-1,k)+
cxz(j,k)*p3(i,j,k)+cxp1z(j,k)*p3(i,j+1,k)+
                                                                                      cxm1zp1(j,k)*p3(i,j-1,k+1)+cxzp1(j,k)*p3(i,j,k+1)+
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        = -cpp1*darcy1*cz5(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      a(k-1) = -cpp1*darcy1*cz4(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        = -cpp1*darcy1*cz6(k)
                                                                                                                                                                                                                       = p1(nxm1, j, k) *2.0*cx4h
                                 +(1.-darcy1)*(
                                                                                                                                                                                         = -cpp1*cx5h + 1.0
                                                                                                     cxp1zp1(j,k)*p3(i,j+1,k+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   = -cpp1*cy5(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                = -cpp1*cy6(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            a(j-1) = -cpp1*cy4(j)
b(j-1) = -cpp1*cy5(j)
c(j-1) = -cpp1*cy6(j)
                                                                                                                                                                         = -cpp1*cx4h*2.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          aux(i,j,k) = d(j-1)
                                                                                                                                                                                                                                                                                                                                                                      d(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 200 i=1, nx
do 200 k=2, nzm1
do 190 j=2, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 do 300 j=2, nym1
do 290 k=2, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          call thomas(nym2)
                                                                                                                                                                                                                                                                                                                                                                                                                                              .. implicit in y
                                                                                                                                                                                                       = 0.0
                                                                                                                                                                                                                                                                                                                  call thomas(nx)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 195 j=2, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      ... implicit in z
                                                                                                                                                                                                                                                                                                                                                                  aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             d(j-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 300 i=1, nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      b(k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        c(k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     d(k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                                                                                                                                                                                                                                                                                                                                                 do 95 i=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                        continue
                                                                                                                                                                         a (nx)
                                                                                                                                                                                                                       d (nx)
                                                                                                                                                                                       p(nx)
                                                                                                                                                                                                        c(nx)
                                                                                                                                                                                                                                                                                                                                                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                     90
                                                                                                                                                                                                                                                                                                                                                                               95
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      200
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          190
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       195
                                                                                                                                                       O
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       O
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     υυ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 darcy1*(p1(i,j,k-1)*cz4(k)+p1(i,j,k+1)*cz6(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 = pl(i,j,k)*(cx5(i) + cy5(j) + darcy1*cz5(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  + darcyl*(p1(1,j,k-1)*cz4(k)+p1(1,j,k+1)*cz6(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              + p1(i-1,j,k)*cx4(i) + p1(i+1,j,k)*cx6(i)
+ p1(i,j-1,k)*cy4(j) + p1(i,j+1,k)*cy6(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /darcy/darcyx,darcyy,darcyz,darcy1,darcy2,darcy3
                                                                                                 /cxz/cxmlzml(nxmax,nzmax),cxz/cxmlzmax,nzmax),
                                                                                                                                                                                /cyz/cymlzml(nymax,nzmax),cyzml(nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   = p1(2,j,k)*2.0*cx61
+ p1(1,j,k)*(cx51 + cy5(j) + darcy1*cz5(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  + p1(1,j-1,k)*cy4(j) + p1(1,j+1,k)*cy6(j)
                                                                                                                 cxplzml(nxmax,nzmax),cxmlz(nxmax,nzmax),
                                                                                                                                                 cxmlzpl(nxmax,nzmax),cxzpl(nxmax,nzmax),
                                                                                                                                                                                                \mathtt{cyp1zm1}(\mathtt{nymax,nzmax}), \mathtt{cym1z}(\mathtt{nymax,nzmax}),
                                                                                                                                                                                                                                  Cymlzp1(nymax,nzmax),cyzp1(nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                              /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                    CXZ(nxmax, nzmax), cxp1z(nxmax, nzmax),
                                common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
                                                                 /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                     cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                    cy4(nymax),cy5(nymax),cy6(nymax)
                                                                                    cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                  Cyz(nymax,nzmax),cyp1z(nymax,nzmax)
common /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /test/testp1,testp2,testp3,testt
                                                                                                                                                                                                                                                                                                                                                                                                                                             /zconsp/cczp4,cczp5,cczp6,cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                                                            /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                             /ploid/ploid(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                             /auxct/auxct(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                               /pbfdc/cx51,cx61,cx4h,cx5h,
                                                                                                                                                                                                                                                                                                                                                                                                                             /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                cy51, cy61, cy4h, cy5h,
cz51, cz61, cz4h, cz5h
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    = -cpp1*cx5(i) + 1.0
= -cpp1*cx6(i)
                                                                                                                                                                                                                                                                                                              /p1/p1(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                             /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                              /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /niterp/niterp2,niterp3
                                                                                                                                                                 cxplzpl(nxmax,nzmax)
                                                                                                                                                                                                                                               cyplzpl(nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /np2p3/nnpmax,nnpmin
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    = -cpp1*cx51 + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      -cpp1*cx4(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      -cpp1*cx61*2.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 700 iij=1,itercmpo
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       ... implicit in x ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 90 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                              /tom/a,b,c,d
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 100 k=2, nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 100 j=2, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     a(i) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      a(1) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  b(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  c(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 d(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   c(1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      b(1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     d(1)
                                                                    common
                                                                                                   Common
                                                                                                                                                                                 common
                                                                                                                                                                                                                                                                common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common
                                                                                                                                                                                                                                                                                                                 Common
                                                                                                                                                                                                                                                                                                                              common
                                                                                                                                                                                                                                                                                                                                                                                              common
                                                                                                                                                                                                                                                                                                                                                                                                                                             common
                                                                                                                                                                                                                                                                                                                                                                                                                                                             common
                                                                                                                                                                                                                                                                                                                                                               common
                                                                                                                                                                                                                                                                                                                                                                               Common
                                                                                                                                                                                                                                                                                                                                                                                                             common
                                                                                                                                                                                                                                                                                                                                                                                                                            common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           common
                                                                                                                                                                                                                                                                                                                                              common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           common
```

0 **0** 0 0 0 0 0

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+ p2(i,1,k)*(cx5(i) + cy51 + darcy2*cz5(k))
+ p2(i-1,1,k)*cx4(i) + p2(i+1,1,k)*cx6(i)
+ darcy2*(p2(i,1,k-1)*cz4(k)+p2(i,1,k+1)*cz6(k))
- darcyz*cczp4*(theta(i,1,k-1)*cz1(k)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /darcy/darcyx,darcyy,darcyz,darcy1,darcy2,darcy3
                                                                                                                                                                                                                                                                                         /cyz/cymlzml(nymax,nzmax),cyzml(nymax,nzmax),
                                                                                              /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                              cyplzml(nymax,nzmax),cymlz(nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                                                                                                                                                                                                                                   cymlzpl(nymax,nzmax),cyzpl(nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                cyz(nymax,nzmax),cyplz(nymax,nzmax),
                                                                                                                                                                                            cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                 cy4(nymax), cy5(nymax), cy6(nymax)
                                                                                                                                                                                                               /cy/cy1(nymax), cy2(nymax), cy3(nymax),
                                                                                                                                                                                                                                                                       cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                       /pconsp/cpp1
/cx/cxl(nxmax),cx2(nxmax),cx3(nxmax).
                                                                                                                                                                                                                                                  common /cz/czl(nzmax),cz2(nzmax),cz3(nzmax)
                                                                                                                                   hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             · theta(i-1,1,k)*cx1(i)*cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                + theta(i,1,k+1)*cz3(k)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  - theta(i+1,1,k)*cx3(i)*cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       + theta(i,1,k)*(cz2(k)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /test/testp1, testp2, testp3, testt
                 a(max),b(max),c(max),d(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   /zconsp/cczp4,cczp5,cczp6,cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /p2old/p2old(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /auxct/auxct(nxmax,nymax,nzmax)
                                                                                                               /h/hx(max), hy(max), hz(max),
                                                                                                                                                                                                                                                                                                                                                                                      /pbfdc/cx51,cx61,cx4h,cx5h,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                           cy51,cy61,cy4h,cy5h,
cz51,cz61,cz4h,cz5h
                                                                                                                                                                                                                                                                                                                                                                                                                                                /p2/p2(nxmax,nymax,nzmax)/p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      a(i-1) = -cpp1*cx4(i)

b(i-1) = -cpp1*cx5(i) + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 = p2(i,2,k)*2.0*cy61
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /niterp/niterp2,niterp3
                                                                                                                                                                                                                                                                                                                                                                        cyplzpl(nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /np2p3/nnpmax,nnpmin
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            c(i-1) = -cpp1*cx6(i)

d(i-1) = p2(i,2,k)*2
                                                      /alpfs/alpp,altp
                                   common /phierr/phierr
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               niterp2 = niterp2 + 1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 700 iij=1,itercmpo
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /tom/a,b,c,d
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          ... implicit in x ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 100 k=2, nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 90 i=2, nxm1
                                                                             /dt/dt
                 dimension
                                                                                                                                                                                                                 common
                                                        common
                                                                             common
                                                                                                                  common
                                                                                                                                                     common
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                                                                                              common
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             solve for new y-component vector potential in porous ***
                                                                                                                                                                                                                                                                                                                                                                         if (plmax.gt.0.001) testpl = testpl/(nxm2*ny*nzm2*plmax)
                                                                                                                                                                                                                                                                                              p1(i,j,k) = p1(i,j,k) + dt*alpp*aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  sumdif = sumdif + abs(plold(i,j,k)-pl(i,j,k))
                                                                                                                                                                                                                                                                                 = testpl + abs(aux(i,j,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                    if (plmax.lt.abspl) plmax = abspl
                                                                                                                                                                                                                                                                                                                                                                                                                to make vector potential steady state
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    sumall = sumall + abs(pl(i,j,k))
                                                                                                                                                                                                                                                                                                                    = abs(pl(i,j,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if ( nnpmin .gt. iij) nnpmin=iij
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if( nnpmax .lt. iij) nnpmax=iij
                                                                d(k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       plold(i,j,k) = pl(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if(sumdiv .lt.phierr) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              sumdiv = sumdif/sumall
call thomas(nzm2)
                                                                                                                                                                                                                               do 600 j=2, nym1
do 600 k=2, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 710 j=1,ny
do 710 k=2,nzm1
                                                         aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   subroutine p2solp
                                                                                                                                                                                                                                                                                                                                                                                                                                                   sumdif = 0.0
sumall = 0.00001
do 710 i=2,nxm1
                                      do 295 k=2,
                                                                                                                                                                                             plmax = 0.0
do 600 i=1, nx
                                                                                                                                                                                                                                                                                 testp1
                                                                                continue
                                                                                                                                                                                                                                                                                                                    absp1
                                                                                                                                       ... update pl
                                                                                                                                                                             testp1 = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   go to 720
                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                                     600 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             * * *
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          end
                                                                           295
300
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       c
720
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           710
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      700
                                                                                                                     0 0 0
```

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```
do 500 i=2, nxml
do 500 j=1, ny
do 490 k=2, nzml
a(k-1) = -cppl*darcy2*cz4(k)
''-1) = -cppl*darcy2*cz5(k) + 1.0
                                                                                                                                                                                                                                                                 do 390 j=2, nyml
a(j) = -cppl*cy4(j)
b(j) = -cppl*cy5(j) +
c(j) = -cppl*cy6(j)
d(j) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                             b(n\dot{y}) = -cp\bar{p}1*c\bar{y}51 + 1.0
                                                                                                                                                                                                            b(1) = -cpp1*cy51 + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                = d(k-1)
                                                                                                                                                                                                                                                                                                                                                                 a(ny) = -cpp1*cy4h*2.0
                                                                                                                                                                                                                              = -cpp1*cy61*2.0
                                                                                     aux(i,ny,k) = d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                           = aux(i,ny,k)
                                                                                                                                                                                                                                          = aux(i,1,k)
                                                                                                                                         ... implicit in y ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            aux(i,j,k) = d(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call thomas(nzm2)
                                           call thomas(nxm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   nzm1
                                                                     do 295 i=2, nxm1
                                                                                                                                                                   do 400 i=2, nxml
do 400 k=2, nzml
a(1) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ... implicit in z
                                                                                                                                                                                                                                                                                                                                                                                             c(ny) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                   call thomas(ny)
                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 395 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 495 k=2,
                                                                                                                                                                                                                                                                                                                                         continue
                   continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                      d(ny)
                                                                                                                                                                                                                          c(1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                               295 contir
300 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  400 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      495 continue
                290
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      490
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                υ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  O
                                                                                                                                                                                                                                                                darcy2*(p2(i,j,k-1)*cz4(k)+p2(i,j,k+1)*cz6(k))
darcyz*cczp4*(theta(i,j,k-1)*cz1(k)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     + darcy2*cz5(k))
                                                                                                                                                                                                                                      + p2(i-1,j,k)*cx4(i) + p2(i+1,j,k)*cx6(i)
+ p2(i,j-1,k)*cy4(j) + p2(i,j+1,k)*cy6(j)
                                                                                                                                                                                                                                                                                                                                                        cymlzml(j,k)*p3(i,j-1,k-1)+cyzml(j,k)*p3(i,j,k-1)+
cyplzml(j,k)*p3(i,j+1,k-1)+cymlz(j,k)*p3(i,j-1,k)+
cyz(j,k)*p3(i,j,k)+cyplz(j,k)*p3(i,j-1,k)+
cymlzpl(j,k)*p3(i,j-1,k+1)+cyzpl(j,k)*p3(i,j,k)+
                                                                                                                                                                                                                                                                                                                                                 cx2(i)*cczp7))+(1.-darcy2)*(
                                                                                                                                                                                                                         = p2(i,j,k)*(cx5(i) + cy5(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       cx2(i)*cczp7))
                                                                                                                                                                                                                                                                                                        + theta(i,j,k+1)*cz3(k)*cczp5
- theta(i+1,j,k)*cx3(i)*cczp7
                                                                                                                                                                                                                                                                                          - theta(i-1,j,k)*cx1(i)*cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             - theta(i-1,ny,k)*cx1(i)*cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         + theta(i,ny,k+1)*cz3(k)*cczp5

- theta(i+1,ny,k)*cx3(i)*cczp7
                                                                                                                                                                                                                                                                                                                                    + theta(i,j,k)*(cz2(k)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       + theta(i,ny,k)*(cz2(k)*cczp5
                                                                                                                                                                            a(i-1) = -cpp1*cx4(i)
b(i-1) = -cpp1*cx5(i) + 1.0
- cx2(i)*cczp7))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              a(i-1) = -cpp1*cx4(i)
b(i-1) = -cpp1*cx5(i) + 1.0
c(i-1) = -cpp1*cx6(i)
                                                                                                                                                                                                           = -cpp1*cx6(i)
                                                                                                                                                                                                                                                                                                                                                                                                                 cyplzp1(j,k)*p3(i,j+1,k+1))
                                                                             aux(i,1,k) = d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                aux(i,j,k) = d(i-1)
                                                                                                                                do 200 j=2, nym1
do 200 k=2, nzm1
do 190 i=2, nxm1
                                   call thomas(nxm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                        call thomas(nxm2)
                                                                do 95 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 195 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 do 290 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 300 k=2, nzm1
                                                                                                                                                                                                          c(i-1)
                                                                                                                                                                                                                       d(i-1)
           continue
                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                    100 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         200 continue
      90
                                                                                                                                                                                                                                                                                                                                                                                                                              190
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            195
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= p3(i,j,2)*2.0*cz61
+ p3(i,j,1)*(cx5(i) + darcy3*cy5(j) + cz51)
+ p3(i-j,j,1)*cx4(i) + p3(i+1,j,1)*cx6(i)
+ darcy3*(p3(i,j-1,1)*cy4(j)+p3(i,j+1,1)*cy6(j))
- darcyy*cczp4*(theta(i-1,j,1)*cx1(i)*cczp6
                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /darcy/darcyx,darcyy,darcyz,darcy1,darcy2,darcy3
                                                                                        common /cyz/cymlzml(nymax,nzmax),cyzml(nymax,nzmax),
                                                                                                              cyplzm1(nymax,nzmax),cym1z(nymax,nzmax),
                                                                                                                                                     cymlzp1(nymax,nzmax),cyzp1(nymax,nzmax),
cyplzp1(nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                   Cyz(nymax,nzmax),cyp1z(nymax,nzmax),
                                    cy4 (nymax), cy5 (nymax), cy6 (nymax)
                common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
cx4(nxmax), cx5(nxmax), cx6(nxmax)
                                                                         cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                   common /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         cx2(i)*cczp6))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       - theta(i,j-1,1)*cy1(j)*cczp5
+ theta(i+1,j,1)*cx3(i)*cczp6
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            - theta(i,j+1,1)*cy3(j)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               + theta(i,j,l)*(-cy2(j)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                /test/testp1,testp2,testp3,testt
                                                                                                                                                                                                                                                                                                                                                 'auxct/auxct(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                         'zconsp/cczp4,cczp5,cczp6,cczp7
                                                                                                                                                                                                                                                                                                                                                                                                                             'intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                       /p3old/p3old(nxmax,nymax,nzmax)
                                                                                                                                                                                        /pbfdc/cx51,cx61,cx4h,cx5h,
                                                                                                                                                                                                                                                                                                                                                                                        't/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                             cy51,cy61,cy4h,cy5h,
cz51,cz61,cz4h,cz5h
                                                                                                                                                                                                                                                  /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                    /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 100 j=2, nym1
do 90 j=2, nxm1
a(i-1) = -cpp1*cx4(i)
b(i-1) = -cpp1*cx5(i) + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /niterp/niterp2, niterp3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     common /np2p3/nnpmax,nnpmin
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        = -cpp1*cx6(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 95 i=2, nxm1
aux(i,j,1) = d(i-1)
                                                                                                                                                                                                                                                                                                                                                                     /phierr/phierr
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      niterp3 = niterp3 + 1
                                                                                                                                                                                                                                                                                                              tom/a,b,c,d
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 do 700 iij=1,itercmpo
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               .. implicit in x
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         call thomas(nxm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   c(i-1)
d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                            common
                                                                                                                                                                                                                                                      common
                                                                                                                                                                                                                                                                                                              common
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                                                                                                                                                                                                                                                                                                                                                                                                           COMMON
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    90
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               O
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         O
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              υ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           solve for new z-component vector potential in porous ***
                                                                                                                                                                                                         if (p2max.gt.0.001) testp2 = testp2/(nxm2*ny*nzm2*p2max)
                                                                                                     testp2 = testp2 + abs(aux(i,j,k))
p2(i,j,k) = p2(i,j,k) + dt*alpp*aux(i,j,k)
absp2 = abs(n2(i,i,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                     sumdif = sumdif + abs(p2old(i,j,k)-p2(i,j,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           hxold(max),hyold(max),hzold(max)
                                                                                                                                                                     if (p2max.lt.absp2) p2max = absp2
                                                                                                                                                                                                                                               to make vector potential steady state
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            dimension a(max),b(max),c(max),d(max)
                                                                                                                                                                                                                                                                                                                                                                                                           = sumall + abs(p2(i,j,k))
                                                                                                                                                       = abs(p2(i,j,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common /h/hx(max),hy(max),hz(max),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if( nnpmin .gt. iij) nnpmin=iij
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if( nnpmax .lt. iij) nnpmax=iij
                                                                                                                                                                                                                                                                                                                                                                                                                             p2old(i,j,k) = p2(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if(sumdiv .lt.phierr) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              common /alpfs/alpp,altp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                sumdiv = sumdif/sumall
                                                              do 600 j=1, ny
do 600 k=2, nzml
                                                                                                                                                                                                                                                                                                                                            do 710 j=1,ny
do 710 k=2,nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                common /pconsp/cpp1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 subroutine p3solp
                                              do 600 i=2, nxm1
                                                                                                                                                                                                                                                                                    sumdif = 0.0
sumall = 0.00001
do 710 i=2,nxm1
           testp2 = 0.0 p2max = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      common /dt/dt
                                                                                                                                                                                                                                                                                                                                                                                                           sumall
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     go to 720
                                                                                                                                                                                       600 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          end if
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     common
```

0 0 0

700

0 0 0 0 0 0 0

.. update p2

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```
a(j-1) = -cpp1*darcy3*cy4(j)

b(j-1) = -cpp1*darcy3*cy5(j)
                                                                                                                                                                                                 = -cpp1*darcy3*cy6(i
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            b(nz) = -cpp1*cz51 + 1.0
                                                                                                                                                                                                                  = aux(i,j,k)
                                                                                                                                                                                                                                                                                                      aux(i,j,k) = d(j-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                   b(1) = -cpp1*cz51 + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      b(k) = -cpp1*cz5(k)

c(k) = -cpp1*cz6(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        a(k) = -cpp1*cz4(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              a(nz) = -cpp1*cz4h*2.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                 c(1) = -cpp1*cz61*2.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  d(k) = aux(i,j,k)
                                  aux(i,j,nz) = d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         = aux(i,j,nz)
                                                                                                                                    do 400 k=1, nz
do 390 j=2, nym1
                                                                                                                                                                                                                                                         call thomas(nym2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                            d(1) = aux(i,j,1)
                                                                                                                                                                                                                                                                                   do 395 j=2, nyml
                                                                                                                                                                                                                                                                                                                                                           ... implicit in z ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 490 k=2, nzml
                   do 295 i=2, nxm1
                                                                                           ... implicit in y
                                                                                                                                                                                                                                                                                                                                                                                                    do 500 \text{ j=2, nyml}
a(1) = 0.0
                                                                                                                       do 400 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                        do 500 i=2, nxm1
                                                                                                                                                                                                  c(j-1)
                                                                                                                                                                                                                 d(j-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call thomas(nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 495 k=1, nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                aux(i,j,k)
                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  testp3 = 0.0 p3max = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          .. update p3
                                                 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             c(nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        d(nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                           300 continue
                                                                                                                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                 395
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          200
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 490
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            495
                                                                             \circ
                                                                                                                                                                                                                                           O
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                                                                                                                                                                                                                                                                                                                                               O
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 U
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          0 0 0
                                                                                                                                                     + p3(i-1,j,k)*cx4(i) + p3(i+1,j,k)*cx6(i)

+ darcy3*(p3(i,j-1,k)*cy4(j)+p3(i,j+1,k)*cy6(j))

+ p3(i,j,k-1)*cz4(k) + p3(i,j,k+1)*cz6(k)

- darcyy*cczp4*(theta(i-1,j,k)*cx1(i)*cczp6
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          = p3(i,j,k)*(cx5(i) + darcy3*cy5(j) + cz5(k))
                                                                                                                                                                                                                                                                                     cymlzml(j,k)*p2(i,j-1,k-1)+cyzml(j,k)*p2(i,j,k-1)+
cyplzml(j,k)*p2(i,j+1,k-1)+cymlz(j,k)*p2(i,j-1,k)+
cyz(j,k)*p2(i,j,k)+cyplz(j,k)*p2(i,j-1,k)+
cymlzpl(j,k)*p2(i,j-1,k+1)+cyzpl(j,k)*p2(i,j+1,k)+
                                                                                                                                                                                                                                                                           cx2(i)*cczp6))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  cx2(i)*cczp6))
                                                                                                                                                                                                              - theta(i,j-1,k)*cy1(j)*cczp5
+ theta(i+1,j,k)*cx3(i)*cczp6
- theta(i,j+1,k)*cy3(j)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     theta(i,j-1,nz)*cy1(j)*cczp5
theta(i+1,j,nz)*cx3(i)*cczp6
theta(i,j+1,nz)*cy3(j)*cczp5
                                                                                                                                                                                                                                                           + theta(i,j,k)*(-cy2(j)*cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  theta(i,j,nz)*(-cy2(j)*cczp5
                                                                                                        b(i-1) = -cpp1*cx5(i) + 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    -cpp1*cx5(i) + 1.0
                                                                                                                        c(i-1) = -cpp1*cx6(i)
                                                                                           a(i-1) = -cpp1*cx4(i)
                                                                                                                                                                                                                                                                                                                                                           cyp1zp1(j,k)*p2(i,j+1,k+1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                a(i-1) = -cpp1*cx4(i)
b(i-1) = -cpp1*cx5(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 = -cpp1*cx6(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                aux(i,j,k) = d(i-1)
                                                         do 200 k=2, nzml
do 190 i=2, nxml
                                                                                                                                                                                                                                                                                                                                                                                                                  call thomas(nxm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                               do 195 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  do 290 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      call thomas(nxm2)
                                           do 200 j=2, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 300 j=2, nym1
                                                                                                                                        d(i-1)
    continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 c(i-1)
                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
95 contir
100 continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            195 continue
                                                                                                                                                                                                                                                                                                                                                                                        190
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          290
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set in lista for fitting Q function.'
                                                                                                                                                                                                                                                                                      pause 'Improper set in lista for fitting Q function.
                                                              dimension covar(ncvm,ncvm),lista(ncvm)
dimension tpnt(ndata),q(ndata),sig(ndata),a(ma),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 16 k=1, j
covar(j,k) +wt*afunc(lista(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          call gaussjdn(covar,mfit,ncvm,beta,1,1)
do 22 j=1,mfit
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     qm=qm-a(lista(j))*afunc(lista(j))
                                                dimension covar(20,20),lista(20)
                                                                                                                                                                                  if (lista(k).eq.j) ihit=ihit+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    call qfunctns(tpnt(i),afunc,ma)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       wt=afunc(lista(j))*sig2i
                                                                                                                                                                                                                                                                  else if (ihit.gt.1) then
                                                                                                  beta(mmax),afunc(mmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          covar(k,j)=covar(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        beta(j)=beta(j)+qm*wt
                                  parameter (mmax=50)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if(mfit.lt.ma) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 15 j=mfit+1,ma
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        if (mfit.gt.1) then
                                                                                                                                                                                                                                                                                                                                                     pause 'Improper
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        a(lista(j))=beta(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      sig2i=1./sig(i)**2
                                                                                                                                                                                                                                                                                                                                      if (kk.ne.(ma+1))
                                                                                                                                                                                                                  if (ihit.eq.0)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 18 i=1,ndata
                                                                                                                                                                                                                                                                                                                                                                                                       covar(j,k)=0.
                                                                                                                                                                   do 11 k=1,mfit
                                                                                                                                                                                                                                                                                                                                                                do 14 j=1,mfit
do 13 k=1,mfit
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 21 j=2,mfit
do 19 k=1,j-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 17 j=1,mfit
                                                                                                                                                                                                                                  lista(kk)=j
                                                                                                                                  do 12 j=1,ma
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                        beta(j)=0.
                                                                                                                kk=mfit+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                    kk=kk+1
                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                                                                                  ihit=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        qm=q(i)
                                                                                                                                                                                                                                                                                                      endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           endi f
                                                                                                                                                                                                                                                                                                                    12
                                                                                                                                                                                                                                                                                                                                                                                                                      13
                                                                                                                                                                                                                                                                                                                                                                                                                                                     14
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      15
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      17
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       16
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         19
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         22
                                                                                                                                    if (p3max.gt.0.001) testp3 = testp3/(nxm2*nym2*nz*p3max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              performing fitting for subroutine asource
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           subroutine qparmfit(tpnt,q,sig,ndata,a,ma,lista,mfit,
                                                     testp3 = testp3 + abs(aux(i,j,k))
p3(i,j,k) = p3(i,j,k) + dt*alpp*aux(i,j,k)
absp3 = abs(p3(i,j,k))
                                                                                                                                                                                                                                                                                        sumdif = sumdif + abs(p3old(i,j,k)-p3(i,j,k))
sumall = sumall + abs(p3(i,j,k))
p3old(i,j,k) = p3(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              constructing basis functions ***
                                                                                                      if (p3max.lt.absp3) p3max = absp3
                                                                                                                                                                       to make vector potential steady state
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            subroutine qfunctns(tpnt,afunc,ma)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if ( nnpmin .gt. iij) nnpmin=iij
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                afunc(i)=tpnt*afunc(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                          if( nnpmax .lt. iij) nnpmax=iij
                                                                                                                                                                                                                                                                                                                                                                          if(sumdiv.lt.phierr) then
                                                                                                                                                                                                                                                                                                                                                         sumdiv = sumdif/sumal1
do 600 1=2, ...
do 600 j=2, nyml
do 600 k=1, nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            dimension afunc(ma)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                covar, ncvm, chisq
                                                                                                                                                                                                                                                                        do 710 k=1,nz
                                                                                                                                                                                                     sumdif = 0.0
sumall = 0.00001
                                                                                                                                                                                                                                                       do 710 j=2,nym1
                                                                                                                                                                                                                                      do 710 i=2,nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              afunc(1) = 1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 11 i=2,ma
                                                                                                                                                                                                                                                                                                                                                                                            go to 720
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                     600 continue
                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               end
                                                                                                                                                                                                                                                                                                                                                                                                                                       c
720
                                                                                                                                                                                                                                                                                                                                         710
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               1,
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integer pstx1,psty1,pstz1

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draw a heating source-temperature curve for confirmation ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     character meshtp*1,exprmnt*8,gridfile*8,srcetype*1,datype*1
character omeshtp*1,oexprmnt*8,ogridfil*8,osrcetyp*1,odatype*1
                                                                                                                                                                                                                                                *(epson*rhof*cpfl+(1.-epson)*rhos*cpsd)/(rhof*cpfl)
points(i)=points(i)*(1000.*dtemp*keff)/(xl1*xl1)
                                                                                                        -1.5)) then
                                                                                                                                                                                        points(i)=points(i)+abest(nterm)*afunc(nterm)
                                                                                                                                                                                                                                                                                                                                                                                                                                                            *** read results from binary input file
                                                                                                                                                                                                                                                                               if( points(i).lt. 0.0) points(i)=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                      (txtemp .le.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                           call qfunctns(txtemp,afunc,nbest)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           divv,divp,dmax
vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           mxp1,mxp2,mxp3,mxt,mxu,mxv,mxw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     v2pl,v2p2,v2p3,v2t,v2u,v2v,v2w,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  mzpl,mzp2,mzp3,mzt,mzu,mzv,mzw
                                                                                                                                                                                                                                     points(i)=points(i)*cc0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       character xc*1,yc*1,zc*1,vpform*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ixl,ixh,iyl,iyh,izl,izh
                                                                                                        .or.
                                                                                                                                                                         do 500 nterm=1,nbest
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          character title*80,otitle*80
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               rt,rpl,rp2,rp3,rmax
                                                                                                     35.)
                                                                                                                                                             points(i)=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             character filename*12
                                                                                                                                                                                                                                                                                                           txtemp=txtemp + 0.5
                                                                                              if (txtemp.ge.
                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                  subroutine reader
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  blup, cgd
                                                                                                               points(i)=0.0
                                                                                 do 91 i=1, 76
                                                                                                                                                                                                                                                                                                                                         call drawcurv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    lfile
                                                                  txtemp=-2.
                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ogical
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  logical
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ogical
                                                                                                                                                                                                                                                                                                                                                        return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ogical
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             ogical
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ogical
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                                                                                                                                                                                                                     endi f
                                                                                                                                                                                                    500
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                       000
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               U
                                                                                                                                                                                                                                            fitting produce respiration heat source to a function ***
                                                                                                                                                                                                                                                                                                                   dimension tpnt(50),q(50),sig(50),a(10),covar(20,20),lista(20)
                                                                                                                                                                                                                                                                                                                                                                              common /porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos
common /epsonnu/epson,xll,annu,gravity,ddd,keff
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   qparmfit(tpnt,q,sig,npt,a,nparam,lista,mfit,
                                                                                                                                                                               subroutine qsource(tpnt,q,npt,nbest,abest)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    find the best fitting for the function ...
                                                                                                      chisq=chisq+((q(i)-sum)/sig(i))**2
                                                                                                                                                                                                                                                                                                                                                               common /ccaa/cc0,dtemp,tcold,thot
                           call qfunctns(tpnt(i),afunc,ma)
                                                                                                                                                                                                                                                                                                                                 dimension abest(10), afunc(50)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                chisq) then
                                                                                                                                                                                                                                                                                                                                                   common /point/points(200)
                                                                          sum=sum+a(j)*afunc(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 13 i=1,mfit
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                covar, nparam, chisq)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           do 9 i=1,npt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 1000 ntry=1,7
    do 6 i=1,10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      lista(i)=i
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         mfit=nparam
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          sig(i) = 0.1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
            do 24 i=1,ndata
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              a(i) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  .gt.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    nparam = nparam
                                                                                                                                                                                                                                                                                                                                                                                                                        sumerr= 9.E30
                                                        do 23 j=1,ma
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        abest(i)=a(i)
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                                                                                           continue
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                                                                                                                                                                                                                                                                                                                                                                                                                                           nparam = 4
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chisq=0
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read(itin) otitle,omeshtp,oexprmnt,osrcetyp,odatype,ogridfil,
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                                           /porous/alphaf,alphap,cpf1,cppr,cpsd,rhof,rhop,rhos
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p2(i,j,k),i=1,nxold),j=1,nyold),k=1,nzold)
p3(i,j,k),i=1,nxold),j=1,nyold),k=1,nzold)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  read(itin)(((theta(i,j,k),i=1,nxold),j=1,nyold),k=1,nzold)
                                                                                                                                                                                                                                                                                                          /darcy/darcyx,darcyy,darcyz,darcy1,darcy2,darcy3
                                                                                                                                                                                                                                 pstx10, psty10, pstz10, pstx11, psty11, pstz11
                                                               /epsonnu/epson,xll,annu,gravity,ddd,keff
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                                                                                                                                                         , pstx2, psty2, pstz2, pstx3, psty3, pstz3
, pstx4, psty4, pstz4, pstx5, psty5, pstz5
                                                                                                                                                                                            ,pstx6, psty6, pstz6, pstx7, psty7, pstz7
,pstx8, psty8, pstz8, pstx9, pstz9
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                                                                                /ccaa/cc0,dtemp,tcold,thot
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                                                                                                                                        /pstxyz/pstx1,psty1,pstz1
                                                                                                                                                                                                                                                                                                                                                                                                                         v(nxmax,nymax,nzmax),
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                                                                                                                                                                                                                                                                                                                                                                                                                                            w(nxmax,nymax,nzmax)
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                                                                                                                     /pst/pstx,psty,pstz
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( hzold(k), k=1,
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        .. read from binary file ...
                                                                                                                                                                                                                                                       /param_q/qparam(20)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          filename=exprmnt // '.bin'
                                                                                                                                                                                                                                                                                                                                             /gridfile/gridfile
                                                                                                                                                                                                                                                                        /nowshow/numshow
                                                                                                 /draw/drawstep
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cct,tmax,pdist,rtime
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            ylci,ylcg,ylca,ylcb,yhci,yhcg,yhca,yhcb,
zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb
/tbi/ixlyl,ixlyh,ixlzl,ixlzh,ixhyl,ixhyh,ixhzl,ixhzh,
iylxl,iylxh,iylzl,iylzh,iyhxl,iyhxh,iyhzl,iyhzh,
izlxl,izlxh,izlyl,izlyh,izhxl,izhxh,izhyl,izhyh
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                                   pstx6, psty6, pstz6, pstx7, psty7, pstz7
, pstx8, psty8, pstz8, pstx9, psty9, pstz9
, pstx10, psty10, pstz10, pstx11, psty11, pstz11
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                                                                                                                                                                                                            /logc/reed,rite,strt,dist,heat,nuss,tran
                                                                                                                                                                                                                                                                                /logpvm/vxp1, vxp2, vxp3, vxt, vxu, vxv, vxw, mxp1, mxp2, mxp3, mxt, mxu, mxv, mxw,
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                                                                                                                                                                                         /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                         vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
mzp1, mzp2, mzp3, mzt, mzu, mzv, mzw
                                                                                                                                                    /tapcom/rfile(94),ifile(67),lfile(10)
pstx2,psty2,pstz2,pstx3,psty3,pstz3
pstx4,psty4,pstz4,pstx5,psty5,pstz5
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                                                                                                                                                                                                                                                                                                                                                                                                  /logtbc/ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /intcom/itercmpo,norun,mainiter
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zlu,zlv,zlw,zhu,zhv,zhw
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /p3/p3(nxmax,nymax,nzmax)
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                                                                                                                                                                                                                                                                /logd/divv,divp,dmax
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if((nxold.ne.nx) .or. (nyold.ne.ny) .or. (nzold.ne.nz) ) then
                                 format(' Warning! New experiment name for output files is',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        .. transform mesh if not same number of mesh points
                                                                                                                                                                                                                 ... set stepsizes between nodes as in binary file
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(*,4020) nxold,nyold,nzold,nx,ny,nz
write(ireport,4020) nxold,nyold,nzold,nx,ny,nz
                                                                                                                                                                                if((meshtp.eq.'b').or.(meshtp.eq.'B')) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               format(' Warning: old mesh .ne. to new mesh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             step size
                                                                               write(ireport,1120) exprmnt, oexprmnt
                                                                                               format(lx,/,'Old experiment name :
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if(hzold(k).ne.hz(k)) tran=
                                                ' not the same as the old name.')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    if(hxold(i).ne.hx(i)) tran=
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 do 21 j=1,ny-1
   if(hyold(j).ne.hy(j)) tran=
                                                                                                                /, 'New experiment name:
                                                                write(*,1120) exprmnt, oexprmnt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ... transform mesh if not same
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                if(tran) write(ireport,4030)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if(tran) write(*,4030)
                  write(ireport,1110)
                                                                                                                                                                                                                                                                                                                              hx(i) = hxold(i)
                                                                                                                                                                                                                                                                                                                                                                             hy(j) = hyold(j)
                                                                                                                                                                                                                                                                                                                                                                                                                            hz(k) = hzold(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 20 i=1,nx-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 22 k=1,nz-1
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                                                                                                                                                                                                                                                  = nxold
= nyold
                                                                                                                                                                                                                                                                                                             do 10 i=1,
                                                                                                                                                                                                                                                                                                                                                            do 11 j=1,
                                                                                                                                                                                                                                                                                                                                                                                                          do 12 k=1,
                                                                                                                                                                                                                                                                               plozn = zn
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                                                                                                                                                                                                                                                                                                                                                                                                                            write(ireport,1050)
format(' Warning! New heating source type is not the same as',
                                                                                                  format(' Warning! New title is not the same as old title.')
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        write(ireport,1070)
format(' Warning! New Darcy numbers may be different.')
                                                                                                                                                                                                                                                                                 format(' Warning! New mesh type is not the same as',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(ireport,1090)
format(' Warning! New grid file is not the same as',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ',a1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(*,1060) srcetype, osrcetyp
write(ireport,1060) srcetype, osrcetyp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write(",1100) gridfile, ogridfil
format(1'v /''Old grid file : ',a8,
                                                                                                                                                                                                                                                                                                                                                      ',a1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      write(*,1080) datype, odatype
write(ireport,1080) datype, odatype
format(1x,/,'Old DATYPE:
',al,
                                                                                                                                                                                                                                                                                                                              write(ireport,1040) meshtp,omeshtp
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                                                                                                                                                                                                                                                                                                                   meshtp,omeshtp
                                                                                                                                                                                                                                                                                                                                                                                               if(srcetype .ne. osrcetyp) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          format(1x, /, 'Old heating type:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if(gridfile .ne. ogridfil) then
                                                                                                                                                                             write(ireport,1020) otitle
format(lx,'New title:',',a80)
                                                                                                                                              format(1x, '01d title:',/,a80)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     if(exprmnt .ne. oexprmnt) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /,'New heating type:
                                                                                                                                                                                                                                if(meshtp .ne. omeshtp) then
                                                                                                                                                                                                                                                                                                                                                format(1x,/,'Old mesh type:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if(datype .ne. odatype) then
                                                    otitle) then
                                                                                                                                     title
                                                                                                                                                                                                                                                                                                                                                               /, 'New mesh type:
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /, 'New grid file:
                                                                                                                                                                      otitle
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /, 'New DATYPE:
                                                                                                                     title
                                                                                                                                  write(ireport,1010)
                                                                                  write(ireport,1000)
                                                                                                                                                                                                                                                                  write(ireport,1030)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     ' old grid file.')
                                                                                                                                                                                                                                                                                             the old type.')
                                                                                                                                                                                                                                                                                                                                                                                                                                                           ' the old type.')
                                                if(title .ne.
                                                                                                                  write(*,1010)
                                                                                                                                                                                                                                                  write(*,1030)
                                                                 write(*,1000)
                                                                                                                                                                    write(*,1020)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          write(*,1070)
                                                                                                                                                                                                                                                                                                                                                                                                               write(*,1050)
endfile itin
                                                                                                                                                                                                                                                                                                                 write(*,1040)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(*,1090)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(*,1110)
                    close(itin)
                                                                                                                                                                                                                                                                                                                                                                                endi f
                                                                                                                                                                                                                   endi f
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             endif
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       endi f
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                                                                                                1000
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                                 O
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/aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                 /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ٠
کر
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          calculate residual for p2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                           +cx5(i)*pl(i,j,k)
+cx6(i)*pl(i+1,j,k)
+cy4(j)*pl(i,j-1,k)
+cy5(j)*pl(i,j,k)
+cy6(j)*pl(i,j+1,k)
+cz4(k)*pl(i,j+1,k)
+cz5(k)*pl(i,j,k-1)
+cz5(k)*pl(i,j,k-1)
                                                                                                                                                                                                                                                                                                    pl(i,j,k)) plmax=pl(i,j,k)
pl(i,j,k)) plmin=pl(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                call mprtz(aux2d,' p1 residuals
                                                                                                                                                                                cx4(i)*p1(i-1,j,
                                          /p1/p1(nxmax,nymax,nzmax)/p2/p2(nxmax,nymax,nzmax)
                                                                   /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        aux2d(i,j) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        residuals
                                                                                                                                                                                                                                                                                                                                                                                                             0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                               do 20 k=2, nzml
do 25 i=2, nxml
do 25 j=2, nyml
                                                                                                                                                                                  II
                                                                                                                                                                                                                                                                                                                                                                                                               п
                                                                                                                                               do 10 j=2, nym1
do 10 k=2, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        D]
                                                                                                                                                                               aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                         aux2d(i,j)
                                                                                                           1000000000
                                                                                                                         plmax=-10000000000
                                                                                                                                                                                                                                                                                                                                                                                            do 15 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  call maxval(aux,'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   subroutine resip2
                                                                                                                                     do 10 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                  .gt.
                                                                                                                                                                                                                                                                                                                                                                              do 15 i=1, nx
                                                                                                                                                                                                                                                                                                                                                                 if(rpl) then
                                                                                                                                                                                                                                                                                                  if( plmax
if( plmin
                                                                                                                                                                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                 common
                                                                                                            p1min=
                                           common
                                                         COMMON
                                                                      Common
                                                                                    common
                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           end
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       U
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             000000
                                                                                                                    call interp(nxold,nyold,nzold,nx,ny,nz,hxold,hyold,hzold,
                                                                                           call interp(nxold,nyold,nzold,nx,ny,nz,hxold,hyold,hzold,
                                                                                                                                               call interp(nxold,nyold,nzold,nx,ny,nz,hxold,hyold,hzold,
                                                                                                                                                                        call interp(nxold,nyold,nzold,nx,ny,nz,hxold,hyold,hzold,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             p_1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /cy/cyl(nymax),cy2(nymax),cy3(nymax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               cy4(nymax),cy5(nymax),cy6(nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       *** calculate residual for
                                                                 format(' Warning: mesh interpolated')
                                                                                                                                                                                                                                                        previously stored vector potential
                                                                                                                                                                                                                                                                                                                         ... initialise old vector potential
                                                                                                                                                                                                                                                                                                                                                                                               p1(i,j,k)
p2(i,j,k)
p3(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /logr/rt,rpl,rp2,rp3,rmax
                                                                                                                                                                                                                                          ... initialize velocities from
                                                                                                                                                                                           hx, hy, hz, theta)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  logical rt,rp1,rp2,rp3,rmax
                                                                                                                                      hx,hy,hz,p2)
                                                                                                           hx, hy, hz, p1)
                                                                                                                                                                  hx, hy, hz, p3)
                                                    write(ireport,4040)
                                                                                                                                                                                                                                                                                                                                                                                                       p2old(i,j,k)
p3old(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                        plold(i, j, k)
                                                                                                                                                                                                                                                                                                                                                              do 5000 j=1,ny
do 5000 k=1,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 subroutine resip1
                        if(tran) then
                                    write(*,4040)
                                                                                                                                                                                                                                                                                                                                               do 5000 i=1,nx
                                                                                                                                                                                                                                                                                  call veloc
                                                                                                                                                                                                                                                                                                call vbc
endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                   continue
                                                                                                                                                                                                                end if
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               common
                                                                                                                                                                                                                                                                                                                                                                                                                                                            return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                        end
                                                                4040
                                                                                                                                                                                                                                                                                                                                                                                                                                 5000
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/geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                             common /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                          b3
                                                                                                                        parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               .
¥
                                                                                                                                                                                                                                                     cx4 (nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                   common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
                                                                                                                                                                                                                                                                                      cy4(nymax), cy5(nymax), cy6(nymax)
                                                                                                                                                                                                                                                                                                                          cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                 common /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax)
                                                                                                                                                                                                                                                                                                     common /cz/czl(nzmax),cz2(nzmax),cz3(nzmax)
                                                    *** calculate residual for
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            +cx5(i)*p3(i, j,k)
+cx6(i)*p3(i+1,j,k)
+cy4(j)*p3(i,j-1,k)
+cy5(j)*p3(i,j,k)
+cy6(j)*p3(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if( p3min .gt. p3(i,j,k)) p3min=p3(i,j,k)
if( p3max .lt. p3(i,j,k)) p3max=p3(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             +cz4(k)*p3(i,j,k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             +cz5(k)*p3(i ,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   +cz6(k)*p3(i,j,k+1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            residuals
                                                                                                                                                                                              /logr/rt,rp1,rp2,rp3,rmax
                                                                                                                                                                                                                                                                                                                                       common /pl/pl(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                        common /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                        common /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  aux2d(i,j) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   call mprtz(aux2d,' p3
                                                                                                                                                         logical rt,rp1,rp2,rp3,rmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 20 k=2, nzml
do 25 i=2, nxml
do 25 j=2, nyml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      aux(i,j,k) =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 п
                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 10 i=2, nxm1
do 10 j=2, nym1
do 10 k=2, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                   p3max = -1000000000
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           aux2d(i,j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 15 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 15 i=1, nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if(rp3) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          continue
                                                                                                                                                                                                                                                                                                                                                                                                                                 p3min =
                                                                                                                                                                                                 common
                                                                                                                                                                                                                   common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  10
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0 0 0 0 0 0 0
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             O
                                common /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
common /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax),
                                                                                                                                                                                                                  common /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                       cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                      common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
                                                                                                         cy4(nymax), cy5(nymax), cy6(nymax)
                                                                                                                          common /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                             cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        p2(i,j,k)) p2max=p2(i,j,k)
p2(i,j,k)) p2min=p2(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                  +cy4(j)*p2(i,j-1,k)
+cy5(j)*p2(i,j,k)
+cy6(j)*p2(i,j+1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     +cz5(k)*p2(i',j,k)
+cz6(k)*p2(i,j,k+1)
                                                                                                                                                                                                                                                                                                                                                                                   +cx6(i)*p2(i+1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                      +cz4(k)*p2(i,j,k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           call mprtz(aux2d,' p2 residuals
                                                                                                                                                                                                                                                                                                                                               cx4(i)*p2(i-1,j,k)
                                                                                                                                                                                                                                                                                                                                                                 +cx5(i)*p2(i
                /logr/rt,rp1,rp2,rp3,rmax
                                                                                                                                                             /p1/p1(nxmax,nymax,nzmax)
                                                                                                                                                                              /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                /p3/p3 (nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        aux2d(i,j) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 call maxval(aux,' p2 residuals
```

do 10 i=2, nxm1 do 10 j=2, nym1 do 10 j=2, nym1 do 10 k=2, nzm1 aux(i,j,k) = c;

p2max=-10000000000. p2min= 10000000000

common common common 0.0

aux2d(i,j)

continue

15

do 15 j=1, ny

do 15 i=1, nx if(rp2) then

if (p2max .1t. if (p2min .gt.

continue

10

U

do 20 k=2, nzml do 25 i=2, nxml do 25 j=2, nyml

continue

25 20

continue

endif

U

return

subroutine resip3

logical rt,rp1,rp2,rp3,rmax

O O common

```
call mprtz(aux2d,'theta residuals',k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        *** setting of constants ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 10 i=1, m-1
if ((pos.ge.f(i)).and.(pos.lt.f(i+1))) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                     call maxval(aux,'theta residuals')
                                                                                                                                                                                                      aux2d(i,j) = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                      subroutine search(pos,f,index,m)
                                                                                                       0.0
                                                                                                                                                   20 k=2, nzml
do 25 i=2, nxml
do 25 j=2, nyml
                                                                                                    aux2d(i,j)
                                                                                    do 15 j=1, ny
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      subroutine setcon
                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     dimension f(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      integer drawstep
                                                               do 15 i=1, nx
                                                if(rt) then
                                                                                                                      continue
                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        go to
                10 continue
                                                                                                                                                                                                                                                                                                                                         return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       endi f
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      - (cy1(j)*v(i,j,k)*theta(i,j,k)

+ cx3(i)*u(i+1,j,k)*theta(i+1,j,k)

+ cx3(i)*u(i+1,j,k)*theta(i+1,j,k)

+ cy2(j)*v(i,j-1,k)*theta(i,j,k)

+ cy2(j)*v(i,j+1,k)*theta(i,j+1,k)

- (cz1(k)*w(i,j,k-1)*theta(i,j,k-1)

+ cz2(k)*w(i,j,k-1)*theta(i,j,k-1)

+ cz3(k)*w(i,j,k+1)*theta(i,j,k)
                                                                                                                                                                                                                                                                                                                                        common /logr/rt,rp1,rp2,rp3,rmax
common /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       aux(i,j,k) = -(cx1(i)*u(i-1,j,k)*theta(i-1,j,k)
                                                                                                                                                                                                         *** calculate residual for theta ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           common /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                                                                                                                                                        parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                         common /cz/czl(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                             cy4(nymax),cy5(nymax),cy6(nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                           cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                                                                                                                                                         common /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax),
                                                                                                                                                                                                                                                                                                                                                                                            cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                        common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            +cy4(j)*theta(i,j-1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             +cy6(j)*theta(i,j+1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            +cz4(k)*theta(i,j,k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             +c26(k)*theta(i,j,k+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           +cy5(j)*theta(i,j
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             cz5(k)*theta(i,j
                                                           -
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      +cx4(i)*theta(i-1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        +cx5(i)*theta(i ,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         +cx6(i)*theta(i+1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          w(nxmax,nymax,nzmax)
                                                       p3 residuals
                                                                                                                                                                                                                                                                                                        logical rt, rp1, rp2, rp3, rmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 10 i=2, nxm1
do 10 j=2, nym1
do 10 k=2, nzm1
                                                  call maxval(aux,'
                                                                                                                                    subroutine resit
    continue
                                                                                     return
                                                                                                                       end
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/dthpnt/dthpnt(nxmax,nymax,nzmax),thmldthl,thmldthh
                                                                                                                                                                                    cc0=rhof*cpf1/(epson*rhof*cpf1+(1.-epson)*rhos*cpsd)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     cc0=cc0*(1.-epson)*xll*xll*rhos/(100000.*dtemp*keff)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           write(*,*) 'Unknown heating source. Program stopped.
                                                                                                                                                                                                                                                                                                                                                                                                                                                            ((srcetype.eq.'C') .or. (srcetype.eq.'c')) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        formulate heat source into a function of temperature
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if ((srcetype.eq.'W').or.(srcetype.eq.'w')) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         ra=2.*gravity*x11*x11*x11*(thot-tcold)*rhof*rhof
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if ( (datype.eq.'r').or.(datype.eq.'R')) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           ra=ra*cpf1/(keff*annu*(thot+tcold+273+273))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 da=da/(175.*(1.-epson)*(1.-epson)*xll*xll)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               call qsource(tpnt,q,npt,nparam,qparam)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  cc0=cc0*x11*x11/(1000.*dtemp*keff)
                                                                                                       rhop=epson*rhof+(1-epson)*rhos
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            da=ddd*ddd*epson*epson
                                                                  .. intermediate variables
                                                                                                                                                                                                       tstrt=(tstrt-tcold)/dtemp
                                                                                                                                                                                                                                                                                                                                                                                                                       heat source unit converting
                                                                                                                             alphap=keff/(rhof*cpf1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   q(i) = q(i) *2.965083333
                                                                                                                                                                                                                                                                                 produce initially alive
                         common /datype/datype
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      determine constants
                                                                                                                                                                                                                                                                                                                                                                                 dthpnt(i,j,k) = 1.
                                                                                                                                                               dtemp=thot-tcold
                                                                                                                                                                                                                                                                                                                          do 89 i=1,nxmax
do 89 j=1,nymax
                                                                                                                                                                                                                                                                                                                                               do 89 j=1,nymax
do 89 k=1,nzmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    darcyx=darcyx*da
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        find Darcy numbers
                                                                                                                                                                                                                            thmldthl = -1
                                                                                                                                                                                                                                              thmldthh=35
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 90 i=1,
                                                                                                                                                 cppr=cpf1
            Common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     endi f
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                                                                                common /reacom/re,ra,pr,arx,ary,arz,betax,betay,betaz,stabr,ccp,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        nmmon /drwstp/drwstp1,drwstp2,drwstp3,drwstp4,drwstp5,
drwstp6,drwstp7,drwstp8,drwstp9,drwstp10,drwstp11,drwstp12
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          'porous/alphaf, alphap, cpfl, cppr, cpsd, rhof, rhop, rhos
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /darcy/darcyx, darcyy, darcyz, darcyl, darcy2, darcy3
   sbetax, sbetay, sbetaz, cbetax, cbetay, cbetaz,
hl, h2, sh1, sh2, h1h2, sh1h2, hmin, denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /cxz/cxmlzml(nxmax,nzmax),cxzml(nxmax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /cyz/cymlzml(nymax,nzmax),cyzml(nymax,nzmax),
                                                                                                                                                                                                      /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   cxplzml(nxmax,nzmax),cxmlz(nxmax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                cyplzml(nymax,nzmax),cymlz(nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      cxmlzpl(nxmax,nzmax),cxzpl(nxmax,nzmax),
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/cyv/cy11v, cy21v, cy31v, cy1hv, cy2hv, cy3hv
/czv/cz11v, cz21v, cz31v, cz1hv, cz2hv, cz3hv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /epsonnu/epson,xll,annu,gravity,ddd,keff
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /txty/tpnt(10),q(10),npt,nparam,srcetype
                                                                                                                                                             /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    Cyz(nymax,nzmax),cyp1z(nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      cxz(nxmax,nzmax),cxplz(nxmax,nzmax)
                                                                                                                                                                                                                                                                                                                                                             /cx/cxl(nxmax),cx2(nxmax),cx3(nxmax),
                                                                                                                                                                                                                                                                                                                                                                                                      /cy/cy1(nymax), cy2(nymax), cy3(nymax),
                                                                                                                                                                                                                                                                                                                                                                                    cx4(nxmax), cx5(nxmax), cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                       cy4(nymax),cy5(nymax),cy6(nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                         /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                            hxold(max),hyold(max),hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /tbfdc/cxf(2,3),cyf(2,3),czf(2,3)
/pbfdc/cx51,cx61,cx4h,cx5h,
                                                                                                                                          /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                       /zconsp/cczp4,cczp5,cczp6,cczp7
                                                                                                        cct, tmax, pdist, rtime
                                                                                                                                                                                                                       /h/hx(max), hy (max), hz (max),
                                                                                                                                                                                                                                                                                                                                           /tconsp/ctp1,ctp2,ctp3,ctp4
                                                                                                                                                                                                                                                              /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /ccaa/cc0,dtemp,tcold,thot
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 cy51,cy61,cy4h,cy5h,
cz51,cz61,cz4h,cz5h
                                         character srcetype*1,datype*1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             cxplzpl(nxmax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       cyp1zp1(nymax,nzmax)
                                                                                                                                                                                                                                                                                   /mapcom/mnx,mny,mnz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /param_q/qparam(20)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /timestep/timestep
                                                                                                                        /alpfs/alpp,altp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /numshow/numshow
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          /draw/drawstep
                                                                                                                                                                                                                                                                                                     /pconsp/cpp1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    /tstrt/tstrt
real sbetax,
                                                                                                                                                                                    /dt/dt
                                                                                                                                                                                                                                                                                                                                                                                                      common
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                                                                                                        +
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real keff

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mainiter=int(real(mainiter)*3600./timestep)
                                                                                                                                                                                                                                                                                                         write(*,*)
write(*,*)'Iteration-number is very large.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 else if (mainiter.1t.10000) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if( mny .eq. 0 ) mny = mnx*ary/arx +0.5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          else if (mainiter.lt.3000) then
            drwstp5 =int(25.*60./timestep+1)
drwstp6 =int(30.*60./timestep+1)
drwstp7 =int(35.*60./timestep+1)
drwstp8 =int(40.*60./timestep+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      else if (mainiter.lt.1000) then numshow=20
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                else if (mainiter.1t.5000) then
                                                                                    drwstp9 =int(45.*60./timestep+1)
drwstp10=int(50.*60./timestep+1)
drwstp11=int(55.*60./timestep+1)
                                                                                                                                                                                                 write(*,*)'max_itheta=',mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       else if (mainiter.lt.500) then
                                                                                                                                          drwstp12=int(60.*60./timestep+1)
                                                                                                                                                                                                                                                                                                                                                                                                ... set massege display internal
                                                                                                                                                                                                                                  if(mainiter.gt.100000) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     else if( mnx .gt. 80 ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              else if (mny .gt. 80 ) then
                                                                                                                                                                                                                                                                                                                                                                                                                                  if (numshow.eq.0) then if (mainiter.1t.100) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if(mnx.eq.0)mnx =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 if(mnx.it.10) then mnx = 10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             if (mny .1t. 10) then mny \approx 10
                                                                                                                                                                                                                                                                                       write(*,*)'Warning!'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      numshow=200
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          numshow=500
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 09=woysmnu
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   numshow=100
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          numshow=10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        else
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       mnx = 80
                                                                                                                                                                                                                                                                                                                                           write(*,*)
                                                                                                                                                                                                                                                                     write(*,*)
                                                                                                                                                                                                                                                       write(*,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                         numshow≈1
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endif
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                                                                                                                                                                                                                                                                                                             ... and calculate nodal positions and find hmin ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           if (drawstep.eq.0) drawstep=1
drawstep=int(real(drawstep)*60./timestep+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (ary/nyml .lt. hmin) hmin=ary/nyml
if (arz/nzml .lt. hmin) hmin=arz/nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              drwstp1 =int( 5.*60./timestep+1)
drwstp2 =int(10.*60./timestep+1)
drwstp3 =int(15.*60./timestep+1)
drwstp4 =int(20.*60./timestep+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         timestep=altp*dt*xll*xll/alphap
                                                                                                                                                                                                                                                                                                                                                                                                                                                         x(i+1) = x(i)+hx(i)
if (hx(i).lt.hmin) hmin=hx(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                y(j+1) = y(j) + hy(j)
if (hy(j) \cdot lt \cdot hmin) \ hmin=hy(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         if (hz(k).lt.hmin) hmin=hz(k)
                                                                                                                                              ... set integer constants ...
                                                                                                         darcy3=darcyy/darcyx
                                                                                       darcy2=darcyz/darcyx
                                                                      darcy1=darcyz/darcyy
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        z(k+1) = z(k) + hz(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    dt = hmin*hmin*stabr
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               ... set time step ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        set draw_time_step
                darcyz=darcyz*da
darcyy=darcyy*da
                                                                                                                                                                                                                                                                                                                                                                                                                                        do 10 i=1, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               do 20 j=1, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 30 k=1, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                    hmin = 1000.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 hmin=arx/nxm1
                                                                                                                                                                                                                                                         = ny-2
                                                                                                                                                                                                      = ny-1
                                                                                                                                                                                                                        nzml = nz-1
                                                                                                                                                                                                                                        nxm2 = nx-2
                                                                                                                                                                                                                                                                            = nz-2
                                                                                                                                                                                                                                                                                                                                                x(1) = 0.0
y(1) = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                                                                                                                                                                                                                                                                                                                                                                                  z(1) =
                                    endif
                                                                                                                                                                                                      nym1
                                                                                                                                                                                    nxm1
                                                                                                                                                                                                                                                                           nzm2
                                                                                                                                                                                                                                                          nym2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            30
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             10
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.. set default map size and lower and upper limits
                                                                                                                                                                                                                                                                   mny =80
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=-denom2*(shz2-shz1)/(denomz*denom)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            =-denom2*(shz2-shz1)/(denomz*denom)
                                                                                                                                                                                                                      = shx2*(shz1-shz2)*denomz/denom
                                                                                                                                                                                                                                          =-shx1*(shz1-shz2)*denomz/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                = shy2*(shz1-shz2)*denomz/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      =-shy1*(shz1-shz2)*denomz/denom
                                                                                                                                                                                      = shx2*shz2*denomz/denom
= shz2*denom2/(denom*denomz)
                                                                                                                                                                                                                                                              =-shz1*denom2/(denomz*denom)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           = shz2*denom2/(denom*denomz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          =-shi1*denom2/(denomz*denom)
                                                                                                                                                                                                          =-shx1*shz2*denomz/denom
                                                                                                                                                                                                                                                    =-shx2*shz1*denomz/denom
                                                                                                                                                                                                                                                                         shx1*shz1*denomz/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   = shy2*shz2*denomz/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      =-shy1*shz2*denomz/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                =-shy2*shz1*denomz/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     shyl*shzl*denomz/denom
                                                                                                                                                                 = denomz*denomz*(shx1-shx2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            denomz*denomz*(shy1-shy2)
                                                                                                                                                      = denomx*denomz*denomz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                  denomy*denomz*denomz
                                                                                                                                  shx1*hx2+shx2*hx1
                                                                                                                                             = shz1*hz2+shz2*hz1
                                                                                                                                                                                                                                                                                                                                                                                                                                                       shz1*hz2+shz2*hz1
                                                                                                                                                                                                                                                                                                                                                                                                                                             = shy1*hy2+shy2*hy1
                                               = hx1*hx1
                                                         = hx2*hx2
                                                                                                            hz2*hz2
                          = hx(i-1)
                                                                               hz (k-1)
                                                                                                     hz1*hz1
                                                                                                                                                                                                                                                                                                                                                           hy1*hy1
                                                                                                                                                                                                                                                                                                                                                                     hy2*hy2
                                                                                                                                                                                                                                                                                                                                      hy (j-1)
                                                                                                                                                                                                                                                                                                                                                                                           hz(k-1)
                                                                                                                                                                                                                                                                                                                                                                                                               hz1*hz1
                                                                                                                                                                                                                                                                                                                                                                                                                         hz2*hz2
                                    = hx(i)
                                                                                          h2 (k)
                                                                                                                                                                                                                                                                                                                                                = hy(j)
                                                                                                                                                                                                                                                                                                                                                                                                     hz (k)
                                                                                                                                                                                      cxmlzml(i,k)
                                                                                                                                                                                                           cxplzml(i,k)
            do 70 k=2,nzm1
                                                                                                                                                                                                                                                     cxmlzp1(i,k)
                                                                                                                                                                                                                                                                         cxplzpl(i,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     cyp1zm1(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                cym1zm1(j,k)
                                                                                                                                                                                                                                                                                                                         do 80 k=2, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               cymlzp1(j,k)
                                                                                 H H
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                                                                                                                                                                                               cxzm1(i,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   cyplzpl(j,k)
                                                                                                                                                                                                                                                                                                                                        n
                                                                                                                                                                                                                      cxm1z(i,k)
                                                                                                                                                                                                                                           cxp1z(i,k)
                                                                                                                                                                                                                                                               cxzp1(i,k)
                                                                                                                                                                                                                                                                                                                                                            п
                                                                                                                                                                                                                                                                                                                                                                                                                                                                             п
                                                                                                                                                                                                                                                                                                                                                                                            п
                                                                                                                                                                                                                                                                                                                                                                                                                                                          n
                                                                                                                                                                                                                                                                                                                                                                                                     п
                                                                                                                                                                                                                                                                                                                                                                                                                и
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    Ħ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          cyzm1(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    cyp1z(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         cyzp1(j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 cym1z(j,k)
  70 i=2,nxm1
                                                                                                                                                                                                                               cxz(i,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          cyz(j,k)
                                                                                                                                                                                                                                                                                                               do 80 j=2, nym1
                                                                                                                                  denomx
                                                                                                                                              denomz
                                                                                                                                                                 denom2
                                                                                                                                                        denom
                                                                                                                                                                                                                                                                                                                                                                                                                                             denomy
                                                                                                                                                                                                                                                                                                                                                                                                                                                        denomz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            denom2
                                               shx1
                                                         shx2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                   denom
                                                                                                              shz2
                                                                                                   shz1
                                    hx2
                          hx1
                                                                                        hz2
                                                                                                                                                                                                                                                                                                                                                                     shy2
                                                                              hz1
                                                                                                                                                                                                                                                                                                                                                         shy1
                                                                                                                                                                                                                                                                                                                                                                                                            shz1
                                                                                                                                                                                                                                                                                                                                                                                                                        shz2
                                                                                                                                                                                                                                                                                                                                              hỷ 2
                                                                                                                                                                                                                                                                                                                                     hy 1
                                                                                                                                                                                                                                                                                                                                                                                                    hz2
                                                                                                                                                                                                                                                                                                                                                                                          hz1
                                                                                                                                                                                                                                                                                            continue
   ဝှ
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if( mnz .eq. 0 ) mnz = mnx*arz/arx +0.5
                                                                                                                                                                                                                   (2.0*(-h1-h2))/denom
(2.0*h1)/denom
                                                                                                                                                                                                                                                                                                                                                                             (2.0*(-h1-h2))/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               (2.0*h2)/denom
(2.0*(-h1-h2))/denom
                                   80 ) then
                                                                         ... calculate fda constants
                                                                                                                                                                                     (-sh1+sh2)/denom
                                                                                                                                                                                                                                                                                                                                                (-sh1+sh2)/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           (-sh1+sh2)/denom
                                                                                                                                                                                                          (2.0*h2)/denom
                                                                                                                                                     = h1*sh2 + h2*sh1
                                                                                                                                                                                                                                                                                                                                                                     (2.0*h2)/denom
                                                                                                                                                                                                                                                                                                                                                                                        (2.0*h1)/denom
                                                                                                                                                                                                                                                                                                                = h1*sh2 + h2*sh1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           h1*sh2 + h2*sh1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    (2.0*h1)/denom
        if (mnz .it. 10) then
                                                                                                                                                                           -sh2/denom
                                                                                                                                                                                                                                                                                                                                     -sh2/denom
                                                                                                                                                                                              sh1/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 -sh2/denom
                                                                                                                                                                                                                                                                                                                                                            sh1/denom
                               else if( mnz .gt.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      = sh1/denom
                                                                                                                                                                                                                                                                      = hy(j-1)
= hy(j)
= h1*h1
                                                                                                           = hx(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                   = hz(k-1)= hz(k)
                                                                                               do 40 i=2, nxm1
                                                                                                                                                                                                                                                               nym1
                                                                                                                                                                                                                                                                                                                                                                                                                      60 k=2, nzm1
                                                                                                                       = hx(i)
                                                                                                                                 = h1*h1
                                                                                                                                           = h2*h2
                                                                                                                                                                                                                                                                                                      h2*h2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                 = h2*h2
                                                                                                                                                                                                                                                                                                                                                                                                                                                       = h1*h1
                       mnz = 10
                                             08≈ zuw
                                                                                                                                                                                                                                                             đo 50 j=2,
h1 = hv
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                                                                                                                                                                                                 11
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                                                                                                                                                                                                                      II
                                                                                                                                                                                                                                                                                                                                                             Ħ
                                                                                                                                                                                                                                                                                                                                     CY1(j)
Cy2(j)
Cy3(j)
Cy4(j)
Cy5(j)
                                                                                                                                                                          cx1(i)
                                                                                                                                                                                  cx2(i)
                                                                                                                                                                                                                  cx5(i)
                                                                                                                                                                                                                              cx6(i)
                                                                                                                                                                                             cx3(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          cz2(k)
cz3(k)
                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               c21(k)
                                                                                                                                                                                                        cx4(i)
                                                                                                                                                                                                                                                                                                               denom
                                                                                                                                                      denom
                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        cz5(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    cz6(k)
                                                       endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                cz4(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                           denom
                                                                                                                                         sh2
                                                                                                                                shl
                                                                                                                                                                                                                                                                                            sh1
sh2
                                                                                                                                                                                                                                                                                                                                                                                                                                           h2
sh1
sh2
                                                                                                                                                                                                                                                                                                                                                                                                                      do
h1
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calculate fda's for velocity boundary conditions ...
                                              = (-sh1h2+sh1)/denom
                                                                                                                                                 = (-sh1h2+sh1)/denom
         denom = h1*sh1h2 - h1h2*sh1
                                                                                                              - h1h2*sh1
                                                                                                                                                                                                                                  - h1h2*sh1
                                                                                                                                                                                                                                                                                                                                 hi*shih2 - hih2*shi
                                                                                                                                                                                                                                                                                                                                                                                                                                    hl*shlh2 - hlh2*shl
                                                                                                                                                                                                                                                                     = (-sh1h2+sh1)/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                              sh1h2/denom
(-sh1h2+sh1)/denom
                                                                                                                                                                                                                                                                                                                                                                     = (sh1h2-sh1)/denom
                                    sh1h2/denom
                                                                                                                                       = sh1h2/denom
                             -sh1/denom
                                                                                                                               = -sh1/denom
                                                                                                                                                                                                                                                                                                                                                   = sh1/denom
= -sh1h2/denom
                                                                                                                                                                                                                                                           sh1h2/denom
                                                                                                                                                                                                                                                    = -sh1/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                     - -shl/denom
                                                                                                    = h1h2*h1h2
                                                                hz(nzm1)
hz(nzm2)
                                                                                                                                                                                                                         = h1h2*h1h2
                                                                                                                                                                                                                                                                                                                         h1h2*h1h2
                                                                                                                                                                                                                                                                                                                                                                                                                           h1h2*h1h2
                                                                                                             h1*sh1h2
                                                                                                                                                                                                                                 = h1*sh1h2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          hy(nym1)
hy(nym2)
h1*h1
                                                                                                                                                                                                                                                                                      = hx(nxm1)
                                                                                                                                                                                                                                                                                                hx(nxm2)
                                                                                           h1+h2
                                                                                                                                                                                    = hx(1)
= hx(2)
= h1*h1
                                                                                   h1*h1
                                                                                                                                                                                                                = h1+h2
                                                                                                                                                                                                                                                                                                                                                                                        hy (1)
hy (2)
h1 *h1
h1 +h2
                                                                                                                                                                                                                                                                                                        h1*h1
                                                                                                                                                                                                                                                                                                                 h1+h2
                             IJ
                                       П
                          czf(1,3) czf(1,2) czf(1,1) czf(1,1)
                                                                                                                              czf(2,3) :
czf(2,2) :
czf(2,1)
                                                                                                                                                                                                                                                              11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                 11
                                                                                                                                                                                                                                                 cx3lv
cx2lv
cx1lv
                                                                                                   sh1h2
                                                                                                              denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                     cy31v
cy21v
cy11v
                                                                                                                                                                                                                       sh1h2
                                                                                                                                                                                                                                 denom
                                                                                                                                                                                                                                                                                                               h1h2
sh1h2
                                                                                          h1h2
                                                                                                                                                                                                                                                                                                                                   denom
                                                                                                                                                                                                                                                                                                                                                    cx1hv
                                                                                                                                                                                                                                                                                                                                                           cx2hv
                                                                                                                                                                                                                                                                                                                                                                      cx3hv
                                                                                                                                                                                                                                                                                                                                                                                                                           sh1h2
                                                                                                                                                                                                                                                                                                                                                                                                                                     denom
                                                                                                                                                                                                      sh1
h1h2
                                                                                                                                                                                                                                                                                                                                                                                                                 h1h2
                                                                                 sh1
                                                                                                                                                                                                                                                                                                        sh1
                                                                                                                                                                                                                                                                                                                                                                                                          sh1
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  υ
                                       calculate fda's for temperature boundary conditions
                                                                                                                                           = (-sh1h2+sh1)/denom
                                                                                                                                                                                                                                              = (-sh1h2+sh1)/denom
                                                                                                                                                                                                                                                                                                                                               (-shlh2+shl)/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                  = (-sh1h2+sh1)/denom
                                                                                                     h1*sh1h2 - h1h2*sh1
                                                                                                                                                                                                         h1*sh1h2 - h1h2*sh1
                                                                                                                                                                                                                                                                                                            - h1h2*sh1
                                                                                                                                                                                                                                                                                                                                                                                                              h1*sh1h2 - h1h2*sh1
                                                                                                                                  = shlh2/denom
                                                                                                                                                                                                                            -sh1/denom
sh1h2/denom
                                                                                                                                                                                                                                                                                                                                      = sh1h2/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                        sh1h2/denom
                                                                                                                         = -sh1/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                 -sh1/denom
                                                                                                                                                                                                                                                                                                                               = -sh1/denom
                                                                                                                                                                                                                                                                                        h1+h2
h1h2*h1h2
                                                                                                                                                                                                h1h2*h1h2
                                                                                                                                                                                                                                                                                                                                                                                                    h1h2*h1h2
                                                                                              h1h2*h1h2
                                                                                                                                                                                                                                                                                                                                                                 hy(nym1)
hy(nym2)
h1*h1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        h1h2*h1h2
                                                                                                                                                                                                                                                                                                            h1*sh1h2
                                                                                                                                                             hx(nxm1)
                                                                                                                                                                      hx(nxm2)
                                                         hx(1)
hx(2)
h1*h1
                                                                                                                                                                              h1*h1
                                                                                                                                                                                                                                                               hy (1)
hy (2)
h1 *h1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                    hz (1)
hz (2)
h1 *h1
h1 +h2
                                                                                    = h1+h2
                                                                                                                                                                                        h1+h2
                                                                                                                                                                                                                                                                                                                                                                                            h1+h2
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                                                                                                                                                                                                                           cxf(2,3)
cxf(2,2)
cxf(2,1)
                                                                                                                                                                                                                                                                                                                            cyf(1,3)
cyf(1,2)
cyf(1,1)
                                                                                                                                                                                                                                                                                                                                                                                                                               cyf(2,3)
cyf(2,2)
cyf(2,1)
            continue
                                                                                                                        cxf(1,3)
cxf(1,2)
                                                                                                                                          cxf(1,1)
                                                                                                                                                                                                                                                                                  П
                                                                                                                                                                                                   П
                                                                                             sh1h2
denom
                                                                                                                                                                                                sh1h2
                                                                                                                                                                                                                                                                                 sh1
h1h2
sh1h2
                                                                                                                                                                                                                                                                                                                                                                                                    sh1h2
denom
                                                                                                                                                                                                         denom
                                                                                                                                                                                                                                                                                                             denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       sh1h2
                                                                           sh1
h1h2
                                                                                                                                                                               sh1
h1h2
                                                                                                                                                                                                                                                                                                                                                                                   sh1
h1h2
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ctp4=rhof*cpf1/(epson*rhof*cpf1+(1.-epson)*rhos*cpsd)
                                                                                                                                                                           ctp3=rhof*cpf1/(epson*rhof*cpf1+(1.-epson)*rhos*cpsd)
ctp2=altp*0.5*dt*rhof*cpf1/(epson*rhof*cpf1+
                                                                                                                                                                                                                                                                                                                                                           *** integration with simpson's rule ***
                                                                            sbetay*cbetaz + sbetax*cbetay*sbetaz
                                                                                                    = cbetay*cbetaz - sbetay*sbetax*sbetaz
                                                                                                                                                                                                                  ctp1=altp*0.5*dt*rhof*cpf1/(epson*rhof*cpf1+
                                                                                                                                                                                                                                                                                                                                                                                                          parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                         subroutine simpsn(fun,nx,hx,answer)
                                                                                                                                                                                                        (1.-epson)*rhos*cpsd)
                                                                                                                                                                                                                                  (1.-epson)*rhos*cpsd
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     answer=answer+4.*fun(i)*hx(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          answer=answer+2.*fun(i)*hx(i-1)
                                                                                                                                                                                                                                                         'Data setting done.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          if(2*(nx/2).eq.nx) modd=.false.if(modd)then
                                    cos(0.0174533*betay)
                         cos(0.0174533*betax)
                                                 cos(0.0174533*betaz)
                                                                                                                                         · · · Constants for temperature
                                                                                                                                                                                                                                                                                                                                                                                                                                                           dimension fun(max), hx(max)
                                                                                        -cbetax*sbetaz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 40 i=2,mx1,2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 50 i=3,mx2,2
                                                                                                                                                                                                                                                                                                                                                                                                                                     logical modd
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            modd=.true.
                                                                                                                 cczp4 = ra
                                                                                                                                                                                                                                                         write(*,*)
                           ij
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      nxml=nx-1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   nxm2=nx-2
                         cbetax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              mx=nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                mx2=mx-2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             answer=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      m×1=mx-1
                                      cbetay
                                                  cbetaz
                                                                                                                                                                                                                                                                     return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   continue
                                                                                       cczp6
                                                                                                     cczp5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                            cczb7
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   mx=nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 else
                                                                                                                                                                                                                                                                                   end
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  40
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                                                                                                                                                                                                                                                                                                                                                                                                calculate fda's for vector potential boundary conditions
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   .. constant for vector potential
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              1.0/(hy(nym1)*hy(nym1))
-2.0/(hy(nym1)*hy(nym1))
                                                                                                                                                                                                                                                                                                                                                                                                                                     1.0/(hx(1)*hx(1))
1.0/(hx(nxm1)*hx(nxm1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                             -2.0/(hx(nxm1)*hx(nxm1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 1.0/(hz(1)*hz(1))
1.0/(hz(nzml)*hz(nzml))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         -2.0/(hz(nzml)*hz(nzml))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     sin(0.0174533*betax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                sin(0.0174533*betay)
sin(0.0174533*betaz)
                           - h1h2*sh1
                                                                                                                                                                      - h1h2*sh1
                                                                                                                                                                                                                                                                                                              - h1h2*sh1
                                                                                                                                                                                                        sh1h2/denom
(-sh1h2+sh1)/denom
                                                                          (shlh2-shl)/denom
                                                                                                                                                                                                                                                                                                                                                            (sh1h2-sh1)/denom
                                                                                                                                                                                                                                                                                                                                                                                                                          -2.0/(hx(1)*hx(1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       -2.0/(hy(1)*hy(1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  1.0/(hy(1)*hy(1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      -2.0/(hz(1)*hz(1))
                                                               -sh1h2/denom
                                                                                                                                                                                                                                                                                                                                               -shlh2/denom
                                                                                                                                                                                            -sh1/denom
           h1h2*h1h2
                                                  sh1/denom
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            alpp*0.5*dt
                                                                                                                                                                                                                                                                                              h1h2*h1h2
                                                                                                                                                                                                                                                                                                                                     sh1/denom
                                                                                                                                                        h1h2*h1h2
                        h1*sh1h2
                                                                                                                                                                    h1*sh1h2
                                                                                                                                                                                                                                                hz(nzm1)
hz(nzm2)
                                                                                                                                                                                                                                                                                                           h1*sh1h2
h1+h2
                                                                                                    hz(1)
hz(2)
h1*h1
                                                                                                                                          h1+h2
                                                                                                                                                                                                                                                                                     h1+h2
                                                                                                                                                                                                                                                                       h1*h1
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 sbetay
          sh1h2
                         denom
                                                             cy2hv
                                                                                                                                                                                                       cz21v
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              sbetaz
                                                                          cy3hv
                                                                                                                                                                    denom
                                                                                                                                                                                            cz31v
                                                                                                                                                                                                                   czllv
                                                                                                                                                                                                                                                                                             sh1h2
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                                                                                                                                                                                                                                                                                                                                                 c22hv
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/tbi/ixlyl,ixlyh,ixlzl,ixlzh,ixhyl,ixhyh,ixhzl,ixhzh,
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izlxl,izlxh,izlyl,izlyh,izhxl,izhxh,izhyl,izhyh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              = (-zhcb - zhcg*czf(2,2)*thera(i,j,nzml)
- zhcg*czf(2,3)*theta(i,j,nzm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    = ( ylcb - ylcg*cyf(1,2)*theta(i,2,k)
- ylcg*cyf(1,3)*theta(i,3,k) )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     - zlcg*czf(1,3)*theta(i,j,3) )
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    xlcg*cxf(1,3)*theta(3,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      = ( xlcb - xlcg*cxf(1,2)*theta(2,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  = ( zlcb - zlcg*czf(1,2)*theta(i,j,2)
                                                                                                                                                                                                                                                                                                                                                                                                                                   gradient conditions using: cg(dt/dn)=ca*t+cb
                                                                                                                                               /tbr/xlci,xlcg,xlca,xlcb,xhci,xhcg,xhca,xhcb,
                                                                                                                                                                           ylci,ylcg,ylca,ylcb,yhci,yhcg,yhca,yhcb,
zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb
                                                                                                                                                                                                                                                                                                                        /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                            resulting in adiabatic / heat flux / convective
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      or isothermal conditions on all boundaries
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                /(xlcg^*cxf(1,1) - xlca)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /(xhcg*cxf(2,1) + xhca)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            /(ylcg*cyf(1,1) - ylca)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /(zlcg*czf(1,1) - zlca)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /(yhcg*cyf(2,1) + yhca)
                                                                                                                                                                                                                                                                                                                                               /tbfdc/cxf(2,3),cyf(2,3),czf(2,3)
                                                                                                                 /logtbc/ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                                                                                                                           common /t/theta(nxmax,nymax,nzmax)
                                                         logical ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       on x=0.0 and x=arx walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     on y=0.0 and y=ary walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                on z=0.0 and z=arz walls
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   theta(nx,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               theta(i,ny,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 10 k=1, nz
theta(1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               theta(i,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 20 k=1, nz
theta(i,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 30 j=1, ny
theta(i,j,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            do 10 \ j=1, ny
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        do 20 i=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                     apply
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                                                                                                                                                                                                                                                                                                                                      * * *
                                                       answer=answer+(fun(nxm1)*hx(nxm2)+fun(nx)*hx(nxm1))/2.
                                                                                                                                                                                                                                                                                                                 *** calculates summary details for flow field
answer=(answer+fun(1)*hx(1)+fun(mx)*hx(mx1))/3.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    *** thermal boundary conditions
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                                                                              parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 40x, '=========',',
40x,'summary of flow field information',',
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    40x, 'nearcannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantannantanna
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               /pl/pl(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    /p3/p3 (nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            w(nxmax,nymax,nzmax)
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(ireport,2010)
                                  modd)then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    call maxmin(p3,' po
write(ireport,2010)
                                                                                                                                                                                                         Sumary
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    call maxmin(p2,'
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*** for solving a tridiagonal system ***
                                                                                                                                                                                                                                                          /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                                                                                                                                                                                                                                    dimension olda(51),oldb(51),oldc(51),oldd(51)
                                                                                                                                                                                              parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   itheta =',itheta
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    write(*,*) ' old a,b,c,d are as followings.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   write(*,*) olda(i),oldb(i),oldc(i),oldd(i)
                                                                                                                                                                                                                           dimension a(max),b(max),c(max),d(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               write(*,*) 'thomas failed! itheta =',
write(*,*) 'part of new a,b,c,d are:'
do 4 i=1,nn
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    do 20 i=nn-1,1,-1 d(i)=( d(i)-d(i+1)*c(i) )*b(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write(*,*) a(i),b(i),c(i),d(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                               b(i)=1.0/aa
d(i)=d(i)-a(i)*b(i-1)*d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                 aa= b(i)-a(i)*b(i-1)*c(i-1)
if (abs(aa).eq.0.) goto 2
                                                                                                                                                                                                                                                                                                                                                                                              2
                                                                                                                                                                                                                                                                       common /itheta/itheta
                                                                          subroutine thomas(nn)
                                                                                                                                                                                                                                                                                                                                                                                             0.) goto
                                                                                                                                                                                                                                           common /tom/a,b,c,d
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          d(nn) = d(nn) *b(nn)
                                                                                                                                                                                                                                                                                                                                                                                         if(b(1) .eq. (
b(1)=1.0/b(1)
                                                                                                                                                                                                                                                                                                                olda(i)=a(i)
oldb(i)=b(i)
oldc(i)=c(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                     do 10 i=2,nn
                                                                                                                                                                                                                                                                                                     do 1 i=1,nn
                                                                                                                                                                                                                                                                                                                                                             oldd(i)=d(i)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 3 i=1,nn
                                             return
                                                                                                                                                                                                                                                           common
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              endi f
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/(zhcg*czf(2,1) + zhca)
                                                                                                                                                                             ... isothermal condition on x = arx wall
                                                                                                                                                                                                                                                                                                                ... isothermal condition on y = 0.0 \text{ wall}
                                                  wall
                                                                                                                                                                                                                                                                                                                                                                                                                                                  .. isothermal condition on y = ary wall
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          0.0 wall
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               arz wall
                                                0.0
                                                  IJ
                                                                                                                                                                                                      if (ixh) then
do 70 j=ixhyl, ixhyh
do 70 k=ixhzl, ixhzh
theta(nx,j,k) = xhci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ... isothermal condition on z =
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               н
                                        ... isothermal condition on x
                                                                                    do 60 j=ixlyl, ixlyh
do 60 k=ixlzl, ixlzh
theta(1,j,k) = xlci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          theta(i,ny,\bar{k}) = yhci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               if (izh) then
do 110 i=izhxl, izhxh
do 110 j=izhyl, izhyh
theta(i,j,nz) = zhci
                                                                                                                                                                                                                                                                                                                                                         do 80 i=iylxl, iylxh
do 80 k=iylzl, iylzh
theta(i,1,k) = ylci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (izl) then
do 100 i=izlxl, izlxh
do 100 j=izlyl, izlyh
theta(i,j,l) = zlci
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     .. isothermal condition on z
                                                                                                                                                                                                                                                                                                                                                                                                                                                                            if (iyh) then
do 90 i=iyhx1, iyhxh
do 90 k=iyhz1, iyhzh
                                                                     if (ixl) then
                                                                                                                                                                                                                                                                                                                                           if (iyl) then
                                                                                                                                    continue
                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                      continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
        30 continue
                                                                                                                                                  endi f
                                                                                                                                                                                                                                                                                     endi f
                                                                                                                                                                                                                                                                                                                                                                                                                       endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        endi f
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           endi f
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                                                                                                                                                              - ctp2*cx5(i)
                                                                                                                                          ctp1*cx1(i)*u(i-1,j,k) - ctp2*cx4(i)
                                                                                                                                                       ctp1*cx2(i)*u(i,j,k) - ctp2*cx5(i)
ctp1*cx3(i)*u(i+1,j,k) - ctp2*cx6(i)
                                                                                                                                                                                                                                                                                                                                                                                                                      ctp3*cy2(j)*v(i,j,k) + ctp4*cy5(j)
ctp3*cz2(k)*w(i,j,k) + ctp4*cz5(k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              = ctp1*cy2(j)*v(i,j,k) - ctp2*cy5(j)
= ctp1*cy3(j)*v(i,j+1,k) - ctp2*cy5(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        - ctp2*cy4(j)
                                                                                                                                                                                                                                                                                                                                                                                     theta(i,j,k)*(-ctp3*cx2(i)*u(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                            + ctp4*cx5(i)
                                                                                                                                                                                        = theta(i-1,j,k)*(-ctp3*cx1(i)
* u(i-1,j,k) + ctp4*cx4(i))
                                                                                                                                                                                                                          + theta(i,j-1,k)*(-ctp3*cy1(j)
                                                                                                                                                                                                                                                         theta(1, ), k-1) * (-ctp3*cz1(k)
                                                                                                                                                                                                                                                                         w(i,j,k-1) + ctp4*cz4(k))
theta(i+1,j,k)*(-ctp3*cx3(i)
u(i+1,j,k) + ctp4*cx6(i))
                                                                                                                                                                                                                                                                                                                       theta(i,j+1,k)*(-ctp3*cy3(j)
                                                                                                                                                                                                                                                                                                                                                     + theta(i,j,k+1)*(-ctp3*cz3(k)
                                                                                                                                                                                                                                           v(i,j-1,k) + ctp4*cy4(j))
                                                                                                                                                                                                                                                                                                                                                                         w(i,j,k+1) + ctp4*cz6(k))
                                                                                                                                                                                                                                                                                                                                          V(i,j+1,k) + ctp4*cy6(j)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    a(j-1) = ctp1*cy1(j)*v(i,j-1,k)
b(j-1) = ctp1*cy2(j)*v(i,j-1,k)
                                                                      qijk=qijk*cc0*dthpnt(i,j,k)
                                                       .lt. 0.0) qijk=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   = d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 = aux(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              aux(i,j,k) = d(j-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                call thomas(nxm2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 200 k=2, nzml
do 190 j=2, nyml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           call thomas(nym2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         do 195 j=2, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 95 i=2, nxm1
                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     aux(i,j,k)
                                                       if(qijk
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             ... implicit in y
                                                                                                                                       a(i-1)

b(i-1)

c(i-1)

d(i-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           d(j-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 200 i=2,nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 c(j-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   heat source
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                     +qi jk
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              95 continue
                  500
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 90
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            190
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            195
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             O
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            O
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              common /dthpnt/dthpnt(nxmax,nymax,nzmax),thmldthl,thmldthh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 .or. (tfruit .le. thmldthl))
                                                                                                                                                                                                                                    /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                  /aux/aux(nxmax,nymax,nzmax),aux2d(max,max)
                                                                              ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            common /txty/tpnt(10),q(10),npt,nparam,srcetype
                                                                   *** solve for new temperature field
                                                                                                                                parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                 cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                  common /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                                                                                                                                                                                                                                      cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                                 common /tconsp/ctp1,ctp2,ctp3,ctp4
common /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /test/testp1,testp2,Testp3,testt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /auxct/auxct(nxmax,nymax,nzmax)
                                                                                                                                                                                 dimension a(max), b(max), c(max), d(max)
common /alpfs/alpp, altp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /told/told(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           qijk=qijk+qparam(nterm)*auxtt
                                                                                                                                                                                                                                                                                                                                                                                                                  /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                 /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /ccaa/cc0,dtemp,tcold,thot
                                                                                                                                                                                                                                                                                                                                                                                     v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                      w(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           tfruit=dtemp*theta(i,j,k)+tcold
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 500 nterm=1,nparam
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          if ( (tfruit .ge. thmldthh)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /param_q/qparam(20)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            auxtt=auxtt*tfruit
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                /sumdivt/sumdivt
                                                                                                                                                                  character srcetype*1
                                                                                                                                                                                                                                                                                                                                                                                                                                  /tom/a,b,c,d
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 100 j=2, nym1
do 100 k=2, nzm1
do 90 i=2, nxm1
subroutine tsolp
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             .. implicit in x
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             dthpnt(i,j,k)=0.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            qijk=0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            auxtt=1.
                                                                                                                                                                                                                    common /dt/dt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           heat source
                                                                                                                                                                                                                                    common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  common
                                                                                                                                                                                                                                                                                                                                                                     Common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   common
                                                                                                                                                                                                                                                                                                                                                                                                                   common
                                                                                                                                                                                                                                                                                                                                                                                                                                   Common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                   common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 common
                                                                                                                                                                                                                                                                                                                                                                                                                                                  common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  common
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timeend=10*second10*second1+60*(minute10*10*minute1)
                                                                                                                                                                                                    /time/date, hour, minutel0, minute1, second10, second1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     timerun=10*second10+second1+60*(minute10*10+minute1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    timestrt=10*second10+second1+60*(minute10*10+minute1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       format('program is terminated at ',all,' ',a9)
                                                                                                                                                                     date, hour, timestrt, timerun, timecal, timeend
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       if (hour .lt. 0) hour=0
minute=nint(real(timeend-3600*hour)/60.-0.5)
                                 program starting, running and ending time
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        write(*,30) timestrg,datestrg
write(ireport,30) timestrg,datestrg
                                                                                                                                                                                  common /fileno/inparam,irg,ireport,itin,itout
                                                                                                                    day*8,colon*1,year*10,exprmnt*8
                                                                                                                                                                                                                                     /timestrt/timestrt,timerun,timecal
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     write(ireport,40)timestrg,datestrg
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         hour=nint(real(timeend)/3600.-0.5)
                                                                                                                                                                                                                                                                     /timestrg/timestrg,datestrg
                                                                                                                 character day*8,colon*1,year*10,
character timestrg*11,datestrg*9
                                                                                                                                                  integer second10, second1, second
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     timeend=timeend-timestrt
                                                                                                                                                                                                                                                                                                                                                                                                                                  kdate10 =ichar(datestrg(1:2))
                                                                                                                                                                                                                                                                                                                    second1 =ichar(timestrg(8:8))
                                                                                                                                                                                                                                                                                                                                                                   minute10=ichar(timestrg(4:4))
                                                                                                                                                                                                                                                                                                                                                                                                                      =ichar(datestrg(2:2))
                                                                                                                                                                                                                                                                                                                                   second10=ichar(timestrg(7:7))
                                                                                                                                                                                                                                                                                                                                                     minutel =ichar(timestrg(5:5))
                                                                                                                                                                                                                                                                                                                                                                                   =ichar(timestrg(2:2))
                                                                                                                                                                                                                                                                                                                                                                                                  khour10 =ichar(timestrg(1:1))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  +3600*(hour+24*date)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    +3600*(hour+24*date)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    else if (runend) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      +3600*(hour+24*date)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     timerun=timerun-timestrt
                                                                                                   start, runng, runend
                                                                                                                                                                                                                      /day/day,colon,year
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     + khour1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                       + kdate1
                                                                                                                                                                                                                                                     /exprmnt/exprmnt
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  else if (runng) then
                                                                                                                                                                                                                                                                                                                                                                                                                                                                   date = 10*kdate10
hour = 10*khour10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  if (start) then
                                                                                                                                                                   integer
                                 **
                                                                                                                                                                                                     common
                                                                                                                                                                                                                                                       common
                                                                                                                                                                                                                                                                       common
                                                                                                                                                                                                                      common
                                                                                                                                                                                                                                     common
                                                                                                                                                                                                                                                                                                                                                                                       khour1
                                                                                                                                                                                                                                                                                                                                                                                                                      kdate1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   30
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   40
0 0 0 0 0 0
                                                                                                                               1.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       write (*,730) ((dthpnt(i,j,((nz+1)/2)),i=2,nxml),j=2,nyml)
                                                                                                                                                                                                                                                                                                                                                                                                                                         testt = testt + abs(aux(i,j,k))
theta(i,j,k) = theta(i,j,k) + dt*altp*aux(i,j,k)
bst = abs(theta(i,j,k))
                                                                                                          - ctp2*cz4(k)
- ctp2*cz5(k)
- ctp2*cz6(k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      if (tmax.gt.0.001) testt = testt/(nxm2*nym2*nzm2*tmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       sumdif = sumdif + abs(told(i,j,k)-theta(i,j,k))
                                                                                                              b(k-1) = ctp1*c22(k)*w(i,j,k) 
c(k-1) = ctp1*c23(k)*w(i,j,k+1)
                                                                                                a(k-1) = ctp1*cz1(k)*w(i,j,k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       = sumall + abs(theta(i,j,k))
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        if (tmax.lt.abst) tmax = abst
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         subroutine ttime(start,runng,runend)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        to make temperature steady state
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        told(i,j,k) = theta(i,j,k)
                                                                                                                                                 d(k-1) = aux(i,j,k)
                                                                                                                                                                                                                                                          d(k-1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         sumdivt = sumdif/sumall
                                                                                                                                                                                                                                                          11
                                          do 300 i=2, nxm1
do 300 j=2, nym1
do 290 k=2, nzm1
                                                                                                                                                                                                    call thomas(nzm2)
                                                                                                                                                                                                                               do 295 k=2, nzml
aux(i,j,k) =
                                                                                                                                                                                                                                                                                                                                                                                do 400 i=2, nxml
do 400 j=2, nyml
do 400 k=2, nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      do 710 k=2, nzml
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        format (1x, 9f4.1)
             implicit in z
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     sumdif = 0.0 sumall = 0.00001
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       do 710 j=2, nym1
                                                                                                                                                                                                                                                                                                                         .. update theta
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     do 710 i=2,nxm1
                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                       continue
                                                                                                                                                                                                                                                                                                                                                       testt = 0.0
tmax = 0.0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                          abst
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          sumall
                                                                                                                                                                                                                                                                                     continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         return
                                                                                                                                                                                                                                                                   295
300
                                                                                                                                                                    290
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          c
c 730
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       400
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      710
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000
                                                                                                                                                                                                                                                                                                       0 0 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          0 0 0 0
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    c×1hv*p3(n×m2,j,k)

                                                                                                                                                                                                                   + cz2(k)*p1(nx,j,k)
+ cz3(k)*p1(nx,j,k+1)
                                                                                                                                                                                     - cx3hv*p3(nx ,j,k)
                                                                                                                                                                                                       + cz1(k)*p1(nx, j, k-1)
                                                                                                                                                                   cx2hv*p3(nxm1, j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       + cy2hv*p3 i, nyml, k)
+ cy3hv*p3 ii, ny , k)
- cz1 (k) *p2 (i, ny, k-1)
- cz2 (k) *p2 (i, ny, k)
- cz3 (k) *p2 (i, ny, k)
                                                                                                                                                                                                                                                                                                                  + cx3hv*p2(nx ,j,k)
- cy1(j)*p1(nx,j-1,k)
                                                                                                                                                                                                                                                                              = cx1hv*p2(nxm2, j, k)
                                                                                                                                                                                                                                                                                             + cx2hv*p2(nxm1,j,k)
                                                                                                                                                                                                                                                                                                                                                  - cy2(j)*p1(nx, j, k)
- cy3(j)*p1(nx, j+1, k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   = cx1(i)*p2(i-1,ny,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  + cx2(i)*p2(i ,ny,k)
+ cx3(i)*p2(i+1,ny,k)
                                                                      - cy1(j)*p1(1,j-1,k)
- cy2(j)*p1(1,j,k)
                                                                                                            cy3(j)*p1(1,j+1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          = cy1hv*p3(i,nym2,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             cx1(i)*p2(i-1,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              cx2(i)*p2(i '1,k)
cx3(i)*p2(i+1,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       cy31v*p3(i,3,k)
cz1(k)*p2(i,1,k-1)
cz2(k)*p2(i,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          cz3(k)*p2(i,1,k+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          cylhv*pl(i,nym2,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            cy2hv*p1(i,nym1,k)
                                  + cx2lv*p2(2,j,k)
+ cx3lv*p2(3,j,k)
                  = cx11v*p2(1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  cyllv*pi(i,1,k)
cy2lv*p1(i,2,k)
cy3lv*p1(i,3,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    cy11v*p3(i,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    cy21v*p3(1,2,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                          y=0 and y=1, ie, j=1 and j=ny planes
                                                                                                                                                     H
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   н
                                                                                                                                                v(nx,j,k)
                                                                                                                                                                                                                                                                              w(nx,j,k)
                  w(1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       u(i,ny,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          do 20 i=2, nxml
do 20 k=2, nzml
u(i,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      w(i,ny,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               w(i,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                       10 continue
                                                                                                                              υ
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                                                                                                                                                                                                                                                                                                                                                                                                                          00000
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    O
                                                                                                                                                                                                       format(1x,'running time =',i4,':',i1,i1,':',i1,i1)
                                                                                                                                             write(ireport,10)hour,minute10,minute1,second10,second1
                                                                                                                                                                                                                                                                                                                                                                       *** calculate velocity at boundary points ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                /geom/nx,ny,nz,nxml,nyml,nzml,nxm2,nym2,nzm2
                                                                                                                                                                                  write(*,10)hour,minute10,minute1,second10,second1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    /cyv/cyllv,cy2lv,cy3lv,cylhv,cy2hv,cy3hv/czv/cz1lv,cz2lv,cz3lv,cz1hv,cz2hv,cz3hv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    /cxv/cxllv,cx2lv,cx3lv,cx1hv,cx2hv,cx3hv
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
                                                                                                                                                                                                                                                                                                                                                                                                                                              parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         cy4 (nymax), cy5 (nymax), cy6 (nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        common /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                      second=timeend-3600*hour-60*minute
second10=nint(real(second)/10.-0.5)
                  minute10=nint(real(minute)/10.-0.5)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     - cx2lv*p3(2,j,k)

- cx3lv*p3(3,j,k)

+ cz1(k)*p1(1,j,k-1)

+ cz2(k)*p1(1,j,k)
                                    if (minute10 .lt. 0) minute10=0
                                                                                                            if (second10 .1t. 0) second10=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              cz3(k)*p1(1,j,k+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   - cx11v*p3(1,j,k)
if (minute .1t. 0) minute=0
                                                    minute1=minute-minute10*10
                                                                                                                              second1=second-10*second10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /vel/u(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        x=0 and x=1 planes, ie, i=1 and i=nx
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              /p1/p1 (nxmax,nymax,nzmax)/p2/p2 (nxmax,nymax,nzmax)/p3/p3 (nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                w(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 10 k=2, nzm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             do 10 j=2, nym1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    v(1,j,k)
                                                                                                                                                                                                                                                                                                subroutine vbc
                                                                                                                                                                    write(*,*)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    common
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            Common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        common
                                                                                                                                                                                                                                           return
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+ cx3hv*p2(nx 'ny,k)
- cy1hv*p1(nx,nym2,k)
- cy2hv*p1(nx,nym1,k)
- cy3hv*p1(nx,ny 'k)
                                                                                                                                                                                                                                                                                                 cx1hv*p2(nxm2,ny,k)
                                                                                                                                                                                                                                                                                                           + cx2hv*p2(nxm1,ny,k)
                                                                                    cylhv*p1(1,nym2,k)
    cy2hv*p1(1,nym1,k)
    cy3hv*p1(1,ny ,k)
                                                                                                                                                                               = cx1hv*p2(nxm2,1,k)
                                                                                                                                                                                           cx2hv*p2(nxm1,1,k)
                                                                                                                                                                                                        cx3hv*p2(nx '1,k)
cy1lv*p1(nx,1,k)
cy2lv*p1(nx,2,k)
                                               = \text{cx1lv*p2}(1, \text{ny, k})
                                                           + cx2lv*p2(2,ny,k)
+ cx3lv*p2(3,ny,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      u(i,1,nz) = cyllv*p3(i,1,nz)
+ cy2lv*p3(i,2,nz)
                                                                                                                                                                                                                                                cy31v*p1(nx,3,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          + cy2lv*p3(i,2,1)
+ cy3lv*p3(i,3,1)
- cz1lv*p2(i,1,1)
- cz2lv*p2(i,1,2)
- cz3lv*p2(i,1,3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  = cy11v*p3(i,1,1)
                                                                                                                                                                                                                                                                                                                                                                                                                along x axis conjunctions
                                                                                                                                                                                                                                                                                                    П
                                                                                                                                                                                                                                                                                                w(nx,ny,k)
                                               w(1,ny,k)
                                                                                                                                                       0=v=n
                                                                                                                                                                                                                                                                       i=nx and j=ny u=v=0
      i=1 and j=ny u=v=0
                                                                                                                                                                               w(nx,1,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           V=W=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      V=W=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               u(i,1,1)
                                                                                                                                                      i=nx and j=1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        j=1 and k=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    and k=nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                       50 i=2,
                                                                                                                                                                                                                                                                                                                                                                            continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                        ф
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     j=1
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           0 0 0 0 0 0
                                                                                                                                                                                                                                                                                                                                                                                                                        - cx1(i)*p3(i-1,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                    - cx2(i)*p3(i , j,nz)
- cx3(i)*p3(i+1,j,nz)
                                                                                                                                                                                                                                                                                                                               = cy1(j)*p3(i,j-1,nz)
+ cy2(j)*p3(i,j,nz)
+ cy3(j)*p3(i,j+1,nz)
- cz1hv*p2(i,j,nzm2)
- cz2hv*p2(i,j,nzm1)
- cz3hv*p2(i,j,nzm1)
                                                                                                                                                                                                                                        - cx1(i)*p3(i-1,j,1)
                                                                                                                                                                                                                                                    - cx2(i)*p3(i 'j,1)
- cx3(i)*p3(i+1,j,1)
                                                                                                                                                        + cy2(j)*p3(i,j,j)
+ cy3(j)*p3(i,j+1,1)
- cz1lv*p2(i,j,1)
- cz2lv*p2(i,j,2)
- cz3lv*p2(i,j,2)
                                                                                                                                                                                                                                                                                                                                                                                                                                                           czlhv*pl(i,j,nzm2)
cz2hv*pl(i,j,nzml)
  <u>ک</u>
                                                                                                                                                                                                                                                                              czllv*pi(i, j, j)
cz2lv*p1(i, j, 2)
cz3lv*p1(i, j, 3)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        cz3hv*p1(i,j,nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             cx2lv*p2(2,1,k)
cx3lv*p2(3,1,k)
cy1lv*p1(1,1,k)
cy2lv*p1(1,2,k)
cy3lv*p1(1,3,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                = cxllv*p2(1,1,k)
cy3hv*p1(i,ny
                                                             z=0 and z=1 planes, ie, k=1 and k=nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          axis conjuctions
                                                                                                                                                                                                                                                                                                                                                                                                                           B
                                                                                                                                                                                                                                           Н
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                do 40 k=2, nzml
                                                                                                                                                                                                                                                                                                                                u(i,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                       v(i,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        and j=1, u=v=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                w(1,1,k)
                                                                                                                            do 30 j=2, nyml
u(i,j,1)
                                                                                                                 do 30 i=2, nxm1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 30 continue
                       20 continue
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*** calculate velocity at internal points
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             common /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           cx4(nxmax),cx5(nxmax),cx6(nxmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     common /cy/cy1(nymax),cy2(nymax),cy3(nymax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       cy4 (nymax), cy5 (nymax), cy6 (nymax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  common /cz/cz1(nzmax),cz2(nzmax),cz3(nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 cz4(nzmax),cz5(nzmax),cz6(nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         common /cx/cx1(nxmax),cx2(nxmax),cx3(nxmax)
                                                                                                                                                                                                                                                                                                                    cx1hv*p3(nxm2,j,nz)
                                                                                                                                                                                                                                                                                                                                    cx2hv*p3(nxm1, j, nz)
                                                                                                                                                                                                                                                                                                                                                - cx3hv*p3(nx ,j,nz)
                                                                                                                                                                    - cx3hv*p3 (nx , j,1)
+ cz1lv*p1 (nx, j,1)
+ cz2lv*p1 (nx, j,2)
+ cz3lv*p1 (nx, j,3)
                                                                                                                                         - cx1hv*p3(nxm2, j, 1)
- cx2hv*p3(nxm1, j, 1)
                                                                                                                                                                                                                                                                                                                                                           czlhv*pl(nx,j,nzm2)
cz2hv*pl(nx,j,nzm1)
                      + czlhv*p1(1, j,nzm2)
+ cz2hv*p1(1, j,nzm1)
        cx31v*p3(3,j,nz)
                                                  + cz3hv*p1(1,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                         cz3hv*p1(nx, j,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /vel/u(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               v(nxmax,nymax,nzmax),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        common /p1/p1(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       /p2/p2(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               w(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                                                                       Н
                                                                                                                                              П
                                                                                                u=w=0
                                                                                                                                                                                                                                                                                                                      v(nx,j,nz)
                                                                                                                                         v(nx,j,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                 subroutine veloc
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   do 10 i=2, nxm1
                                                                                                                                                                                                                                                                         i=nx and k=nz
                                                                                               i=nx and k=1
                                                                                                                                                                                                                                                                                                                                                                                                        continue
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 common
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           common
                                                                                                                                                                                                                                                                                                                                                                                                                      return
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        common
                                                                                                                                                                                                                                                                                                                                                                                                                                     end
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     O
                                                                                                                                                                                                                                                                                                                                                    cy2hv*p3(i,nym1,nz)
cy3hv*p3(i,ny ,nz)
cz1hv*p2(i,ny,nzm2)
                                                                                                                                                                                                                                                                                                                                        = cy1hv*p3(i,nym2,nz)
                                                                                                                                                                                                                                                                                                                                                                                              cz2hv*p2(i,ny,nzml)
                                                                                                                                                                           + cy2hv*p3(i,nym1,1)
+ cy3hv*p3(i,ny '1)
- cz1lv*p2(i,ny,1)
- cz2lv*p2(i,ny,2)
- cz3lv*p2(i,ny,3)
                                                                                                                                                                                                                                                                                                                                                                                                             cz3hv*p2(i,ny,nz
             - cz1hv*p2(i,1,nzm2)
- cz2hv*p2(i,1,nzm1)
                                                                                                                                                               cy1hv*p3(i,nym2,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            - cxllv*p3(1,j,nz)
- cx2lv*p3(2,j,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                cx2lv*p3(2,j,1)
cx3lv*p3(3,j,1)
cz1lv*p1(1,j,1)
cz2lv*p1(1,j,2)
cz3lv*p1(1,j,3)
                                            cz3hv*p2(i,1,nz
cy31v*p3(i,3,nz)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   cx11v*p3(1,j,1)
                                                                                                                                                                 11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              v(1,j,nz) =
                                                                                                                                                                                                                                                                                                                                        u(i,ny,nz)
                                                                                                                                                                                                                                                                                 0=%=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         0=w=n
                                                                                                                                                            u(i,ny,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     n=w=0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 v(1,j,1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              do 60 j=2, nym1
                                                                                                     v=w=0
                                                                                                                                                                                                                                                                                j=ny and k=nz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                        axis
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    i=1 and k=nz
                                                                                                    j=ny and k=1
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       i=1 and k=1
                                                                                                                                                                                                                                                                                                                                                                                                                            continue
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zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb
common /tbi/ixlyl,ixlyh,ixlzl,ixlzh,ixhyl,ixhyh,ixhzl,ixhzh,
iylxl,iylxh,iylzl,iylzh,iyhxl,iyhxh,iyhzl,iyhzh,
izlxl,izlxh,izlyl,izlyh,izhxl,izhxh,izhyl,izhyh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /porous/alphaf,alphap,cpfl,cppr,cpsd,rhof,rhop,rhos/epsonnu/epson,xll,annu,gravity,ddd,keff
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /tbr/xlci,xlcg,xlca,xlcb,xhci,xhcg,xhca,xhcb,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             /geom/nx,ny,nz,nxm1,nym1,nzm1,nxm2,nym2,nzm2
                                                                                                      pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                                                                                                             /logc/reed,rite,strt,dist,heat,nuss,tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           /vmppos/rmx(nxmax),rmy(nymax),rmz(nzmax)
                                                                                                                                                                                                                                                                                                                                           /logpvm/vxp1,vxp2,vxp3,vxt,vxu,vxv,vxw,
                                                                                                                                                                                                                                     /fileno/inparam,irg,ireport,itin,itout
                                                                                                                                                                                                                                                                                                                                                                    mxp1, mxp2, mxp3, mxt, mxu, mxv, mxw,
                                                                                                                                                                                                                                                                                                                                                                                     vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw,
myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                                                                            vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
                                                                                                                                                                                       /tapcom/rfile(94),ifile(67),lfile(10)
                                                                                                                                                                                                                                                                                                                                                                                                                                                   mzp1, mzp2, mzp3, mzt, mzu, mzv, mzw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /vmploc/mx(nxmax),my(nymax),mz(nzmax)
                 , pstx2, psty2, pstz2, pstx3, psty3, pstz3
, pstx4, psty4, pstz4, pstx5, psty5, pstz5
                                                           ,pstx6,psty6,pstz6,pstx7,psty7,pstz7
,pstx8,psty8,pstz8,pstx9,psty9,pstz9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       hxold(max), hyold(max), hzold(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            pstx2,psty2,pstz2,pstx3,psty3,pstz3
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /logtbc/ixl,ixh,iyl,iyh,izl,izh
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        /intcom/itercmpo,norun,mainiter
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          common /velbc/xlu,xlv,xlw,xhu,xhv,xhw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 ylu,ylv,ylw,yhu,yhv,yhw,
zlu,zlv,zlw,zhu,zhv,zhw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   cct, tmax, pdist, rtime
                                                                                                                                                                                                                                                                                                  /logr/rt,rpl,rp2,rp3,rmax
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         /axis/x(max),y(max),z(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       /ccaa/cc0,dtemp,tcold,thot
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /h/hx(max), hy(max), hz(max)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /pstxyz/pstxl,pstyl,pstzl
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /vmpfrm/xc,yc,zc,vpform
                                                                                                                                                                                                                                                                                                                        /logd/divv,divp,dmax
                                                                                                                                                                     /title/title,otitle
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /pst/pstx,psty,pstz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     /vmpnum/npx,npy,npz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 /mapcom/mnx,mny,mnz
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  /alpfs/alpp,altp
                                                                                                                                                                                                            /exprmnt/exprmnt
                                                                                                                                                                                                                                                        /logi/blup,cgd
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      /phierr/phierr
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         write results to binary files ***
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      parameter(nxmax=51,nymax=51,nzmax=51,max=51)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       reed, rite, strt, dist, heat, nuss, tran
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         character title*80,otitle*80,filename*12
                                                                                                                                                                                                                                                                                                                                                                         cx2(i)*p2(i ,j,k)
cx3(i)*p2(i+1,j,k)
cy1(j)*p1(i,j-1,k)
cy2(j)*p1(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        vxp1, vxp2, vxp3, vxt, vxu, vxv, vxw
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          mxp1,mxp2,mxp3,mxt,mxu,mxv,mxw,
                                                                                                                                                                                                       cx1(i)*p3(i-1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               vyp1, vyp2, vyp3, vyt, vyu, vyv, vyw, myp1, myp2, myp3, myt, myu, myv, myw,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        vzp1, vzp2, vzp3, vzt, vzu, vzv, vzw,
                                                                                                                                                                                                                                            cx3(i)*p3(i+1,j,k)
                                                                                                                                                                                                                                                                 cz1(k)*p1(i,j,k-1)
cz2(k)*p1(i,j,k
                                                                                                                                                                                                                                                                                                           c23(k)*p1(i,j,k+1)
                                                                                        cy3(j)*p3(i,j+1,k)
cz1(k)*p2(i,j,k-1)
cz2(k)*p2(i,j,k)
                                                 cy1(j)*p3(i,j-1,k)
                                                                                                                                                                                                                                                                                                                                                      cx1(i)*p2(i-1,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           mzpl, mzp2, mzp3, mzt, mzu, mzv, mzw
                                                                                                                                                         cz3(k)*p2(i,j,k+1)
                                                                                                                                                                                                                                                                                                                                                                                                                                          cy2(j)*p1(i,j,k)
cy3(j)*p1(i,j+1,k)
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                                                                                                                                                                                                                     cx2(i)*p3(i
                                                                    cy2(j)*p3(i,j
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ix1, ixh, iy1, iyh, iz1, izh
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  divv, divp, dmax
do 10 j=2, nym1
do 10 k=2, nzm1
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                                               u(i,j,k)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    subroutine writer
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                                                                                                                                                                                                   v(i,j,k)
                                                                                                                                                                                                                                                                                                                                                    w(i,j,k)
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pstx10, psty10, pstz10, pstx11, psty11, pstz11,
ixly1, ixlyh, ixlz1, ixlzh, ixhy1, ixhyh, ixhz1, ixhzh,
iylx1, iylxh, iylz1, iylzh, iyhx1, iyhxh, iyhz1, iyhzh,
izlx1, izlxh, izly1, izlyh, izhx1, izhxh, izhy1, izhyh,
                                                                                                                                                                                                                                                                                                                                                                                                                    u2)
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k=1,
k=1,
                                                                                                                                                                                                                                                                                                                                                                               k=1,
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                                      pstx8,psty8,pstz8,pstx9,psty9,pstz9,
                    pstxé,psty6,pstz6,pstx7,psty7,pstz7,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              program AGRI_3D.FOR (7785 lines) CCCCCCC
                                                                                                                                                                                                                                                                                                                                                                          j=1,
j=1,
                                                                                                                                                                                                                                                                                                                                                                                                                                  j=1,
                                                                                                                                                                                                                                                                                                                                                                 write(itout) ((( p1(i,j,k), i=1, nx),
write(itout) ((( p2(i,j,k), i=1, nx),
write(itout) ((( p3(i,j,k), i=1, nx),
write(itout) (((theta(i,j,k), i=1, nx),
                                                                                                                                                                           ixl, ixh, iyl, iyh, izl, izh
                                                                                                                                                                                                                                                   write(itout) ( hx(i), i=1, nx-1)
write(itout) ( hy(j), j=1, ny-1)
write(itout) ( hz(k), k=1, nz-1)
                                                                                                                                                     cgd,dist,heat,tran,
                                                                                                                                                                                                             write mesh to binary file
                                                                                                                                                                                                                                                                                                                              .. write to binary file ...
                                                                                                                                                                                                                                                                                                                                                                                                                                                              endfile itout
                                                                                                                                  write lfile
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write(itout) title,meshtp,exprmnt,srcetype,datype,gridfile,
                                                                                                                                    /darcy/darcyx, darcyy, darcyz, darcyl, darcy2, darcy3
                                                                                                                                                                                                                                                                                                                                                                                                       .. record total number of iterations and total cpu time
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           stabr,alpp,altp,phierr,ccp,cct,dt,seccpu,ra
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    ylci,ylcg,ylca,ylcb,yhci,yhcg,yhca,yhcb,
zlci,zlcg,zlca,zlcb,zhci,zhcg,zhca,zhcb,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   norun,nx,ny,nz,itercmpo,iterpp,mainiter,
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                                                      ,pstx10,psty10,pstz10,pstx11,psty11,pstz11
                                                                                                                                                                                           /txty/tpnt(10),q(10),npt,nparam,srcetype
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     open(unit=itout,file=filename ,status='unknown'
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     npt,nparam,itnum,pstx1,psty1,pstz1,
pstx2,psty2,pstz2,pstx3,psty3,pstz3,
pstx4,psty4,pstz4,pstx5,psty5,pstz5,
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         arx, ary, arz, betax, betay, betaz,
                 , pstx6, psty6, pstz6, pstx7, psty7, pstz7
, pstx8, psty8, pstz8, pstx9, psty9, pstz9
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              (tpnt(i), i=1,10), (q(i), i=1,10),
pstx4,psty4,pstz4,pstx5,psty5,pstz5
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               Ylu, ylv, ylw, yhu, yhv, yhw,
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                                                                                                                                                                                                                                                                                         /t/theta(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                 /vel/u(nxmax,nymax,nzmax),
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                                                                                                                                                                                                                                                      v (nxmax, nymax, nzmax),
                                                                                                                                                                                                                                                                                                            /p1/p1(nxmax,nymax,nzmax)/p2/p2(nxmax,nymax,nzmax)/p3/p3(nxmax,nymax,nzmax)
                                                                                                                                                                                                                                                                         w(nxmax,nymax,nzmax)
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                                                                            /param_q/qparam(20)
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                                                                                                                                                                       /gridfile/gridfile
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                                                                                               /nowshow/numshow
                                                                                                               /iterpp/iterpp
                                                                                                                                                                                                              /datype/datype
                                                                                                                                                       /tstrt/tstrt
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Input file INPARAM (SAMPLE)

| K=1 *-U-* *-V-* *-W-* 0.0 0.0 NA C PRINTING FORM AND PI ** { <i>NTEGER NUI I VAR-X: P1* P2* P3* T T T T MAP-X: P1* P2* P3* T T T T T T T T T T T T T T T T T T T</i> | (4) | *Y1-* *Y2-* *Y3-* *Y 06 0 0 VAR-Z: P1* P2* P3* T T T MAP-Z: P1* P2* P3* **{ <p>LANE NOS. C</p> | *21- 0 C *RT- | DIVV* DIVP* DMAX T T **{EXPRMNT sample {npt,nparam, & s ** ** 8 7 C | *tpnt(1)* -1.0 *tpnt(6)* 20.0 *0(1)* 1.0 *0(6)* *0(6)* | *-DARCYX-* *-DARCYY- 1.0 1.0 1.0 1.0 1.0 gridfile n |
|---|---|---|---|---|--|--|
| <pre>rriptions of this job. Up to 80 letters.) * e.28h.28l.28w, adiabatic floor, cooling from 30. 2.0000E-05 1.0056E-00 3.7240E+00 1.2339E-00 1.0660E+03 * *XLL * *ANNU * *GRAVITY * *DDD * cool 0.28000000 0.000014194 9.80000000 0.067000000 * *THOT * *TSTRT * *COLD, HOT WALL, INITIAL TEMP</pre> | . * * - BETAY . 0 . N=NON-UN . * *CCP 03 1.000E P* Positions | Z* * X * Z * * X * | HEAT* NUSS* T T SCALE USING AR'S: DEF'LT MNX=51) *-PDIST* | I=NX (IE. X=ARX) *PATCH <t f=""> *-CI* YL* YH* ZL* Z 11 F 0.00 1 11 1 B} *-G-**-B-*(G(DT/DX)=A*T+ 1.00 0.00 0.00 J=NY (IE. Y=ARY) *PATCH<t f=""> *-CI* XL* XL* ZL* Z</t></t> | T | I=NX *-U-* *-V-* *-W-* NA 0.0 0.0 J=NY *-U-* *-V-* *-W-* |
| put file {Desc ples, siz -KEFF* 291E-03 383208 TCOLD | *ARX* *ARY* *ARZ* 1.0 *MESHTYPE* *-NX* *-NY* *-NZ* (MES 1.1 1.1 *STABR-* *ALPP* *ALTP* 20.00 *ITERCMPO* *-ITERPP-* *MAINITER* 2 | *X* *Y* *Z 5 7 8 *X* *Y* *Z 8 7 8 *X* *Y* *Z 11 7 6 | REED* RITE* STRT* DIST* HEAT F F F *MNX* *MNY* *MNZ* {IF 0, SC! 0 0 0 0 | ARY CO YL* Y 1 [G(DT/ XL* X | * 0 / * 0 | VELOCITY BOUNDARY CONDITIONS I=1 *-U-* *-V-* *-W-* NA 0.0 0.0 J=1 *-U-* *-V-* *-W-* 0.0 NA 0.0 |

| K=NZ *-U-* *-V-* *-W-* 0.0 0.0 NA | TROLS : <c>OORDINATE NUMBERING)</c> | W-* X=CONSTANT (Y-Z) PLANES W-* T | 3 *X6-* *X7-* *X8-* *X9-* *X10* *X11* 0.0 0.0 0.0 0.0 0.0 * W-* Y=CONSTANT (X-Z) PLANES T T T T T T T | EN) ** { 0.1 * *Y7-* *Y8-* * 0.0 * *Y7-* *Y8-* * | W-* Z=CONSTANT (X-Y) PLANES W-* W-T GIVEN ** (NUMBER OF PLANES) | 01 -* *Z7-* *Z8-* *Z9-* *Z10* 6 7 8 9 10 | - (RESIDUALS) | ICE) no space and ONLY 8 characters.) | of points, parameters & type of source}.Co2/Kg h & w or W for w/mmm } | (3) * *tpnt(4) * *tpnt(5) 5.0 | Q(3)* *Q(4)* *Q(5)* 8.0 | -* * (r or R = ratio, v or V = values .0 r ace and ONLY 8 characters.) SECTION |
|---|--|--|--|---|---|---|---|--|---|--|--|---|
| K=1 *-U-* *-V-* *-W-* 0.0 0.0 NA | RINTING FORM AND PRINTING CON | J VAR-X: P1* P2* P3* T-* U-* V-* W T T T T T T T T T T T T T T T T T T T | P *X1-* *X2-* *X3-* *X4-* *X5-* *X6 03 6 9 0.0 0.0 0 0AR-Y: P1* P2* P3* T-* U-* V-* W MAP-Y: P1* P2* P3* T-* U-* V-* W | <pre><p>LANE NOS. OR <c>OORD. *Y2-* *Y3-* *Y4-* *Y5-* * 0 0 0 0</c></p></pre> | VAK-Z: P1* P2* P3* T-* U-* V-* W | *Z1-* *Z2-* *Z3-* *Z4-* *Z5-* *Z6 06 0 0 4 5 | *RT-* *RP1* *RP2* *RP3* RMAX* <- T T T T T T T C | DIVP* DMAX* < (DIVERGEN T T There must be | srcetype. Number {c or C for mg_ | pnt(1)* *tpnt(2)* *t -1.0 0.0 pnt(6)* *tpnt(7)* *t | Q(1)* *Q(2)* * 0.0 4.5 Q(6)* *Q(7)* * 41.0 50.0 (numshow: 0=auto) | *-DARCYX-* *-DARCYY-* *-DARCYZ-* 1.0 1.0 1.0 ** (gridfile name, no space gridfile |

| variable title Effective thermal conductity of packed fruits or vegetables. alphaf Specific heat of fruits or vegetables. Thermal diffusivity of air. cpsd Specific heat of fruits or vegetables. Thos Density of air. Thos Density of fair. Density of fair. Thos Density of fair. Thos Density of fair. Thos Density of fair. Gravity force. ddd cold wall temperature. Hot wall temperature. Thoe of these aspect ratios must be = 1) betax, betay, Reation of box about x-axis , y-axis and betaz. arx, ary, arz Aspect ratios in x-, y- and z- directions. (One of these aspect ratios must be = 1) Betax, betay, Reation of box about x-axis , y-axis and betaz. arx, ary, arz Aspect ratios in x-, y- and z directions. (One of these aspect ratios must be = 1) Betax, betay, Read from previously written binary file. meshtp u: Uniform mesh on the greeting in file 'GRIDFILE') betax betay are previously written binary file. In Number of mesh points in x, y and z directions. (not used for non-uniform or previous mesh.) stabr Stabr Stabrilty ratio (delta t / delta h(min)**2). alpp, alt Prase transient factors. Maximum number of iterations for each component of vector potential. iterpp Maximum number of iterations for all components directions. Arawstep Time interal for coutput results. | | |
|--|--|-------------------------------|
| To be Effect or very or representations of the property of the | | ssnu |
| Speci Densi Densi Densi Densi Densi Visco Gravi Stavi Stavi Aspec (One (One (One (One (One (One (One (One | f the job report. ty of packed fruits | m'x'um |
| y Gravi Diame Cold | vegetables. ables. dia. | pdist |
| betay, Rotat betay, Rotat z-axi | ous media. | Tempe These Only |
| Type u: n: n: n: n: n: n: not ltp Ralse ltp Make in ev t Conve mpo compc maxin ev t to re ter Maxin ev | <pre>d z- directions. os must be = 1) is , y-axis and a right hand rule).</pre> | ixl xlci ixlyl ixlyl |
| | <pre>include: d in file 'GRIDFILE') written binary file in file 'GRIDFILE') , y and z directions. i or previous mesh.}</pre> | xlcg, |
| | <pre>delta h(min)**2). r potential components i and theta.</pre> | Veloc |
| pstz11 | ns for each ial. ns for all components e. erations. sults. for transient esults. | Only xlv,x Print |
| reed t: Read the starting values from binary file f: Fields initialised in subroutine INITAL. | change it to reset accumulated iteration count and CPU usage) arting values from binary file. ialised in subroutine INITAL. olution to binary file at end. | The p |

| dist | Disturb |
|---|--|
| nuss | L: Energy equation Solved. f: Temperature set to zero. Energy equation disabled. t: Calculate and print Nusselt numbers. |
| mnx,mny,mnz pdist | Map dimensions (x, y and z respectively). (Map dimensions are reset to a minimum of 10 and a maximum of 80.) (Maps scaled for a printer with a pitch ratio of 61 horiz./49 vert see subroutine map.) (If mnz=0 then mnx*(arz/arx) is used, If mny=0 then mnx*(ary/arx) is used, and If mnx=0 then mnx is set to 51.) If dist is true, then all vector potentials (except on the boundaries) are disturbed by multiplying each value by 1+random[-1.1]*polist. |
| Temperature Bou | ions |
| These variables x=(Only the x=0 wa | are re), x=a: |
| ixl xlci ixlyl,ixlyh ixlzl,ixlzh | Set isothermal patch at $x=0$ <trvue <f="" or="">alse Theta of isothermal patch, on $x=0$ wall [0, 1] Start & end of patch in y-direction [1, ny] Start & end of patch in z-direction [1, nz]</trvue> |
| xlcg,xlca,xlcb | Specifies heat flux condition, on the x=0 wall using xlcg*(dt/dx) = xlca*t + xlcb. This condition applies on all the wall, except On the isothermal patch (if defined - see ixl) (eg adiabatic : xlcg=1, xlca=0, xlcb= 0 heat flux : xlcg=1, xlca=0, xlcb= 1 convective : xlcg=1, xlca=1, xlcb= 1 isothermal(t=1): xlcg=1, xlca=1, xlcb= 1 isothermal(t=1): xlcg=0, xlca=1, xlcb= 1 tonvec: This permits patch to be set to say t=0 while rest of wall is at say t=1} |
| Velocity Boundary Conditions These variables are repeated x=0, x=arx; y=0nly the x=0 variables are pre- | <pre>idary Conditions</pre> |
| xlv,xlw | Tangential velocities (v & w) on the $x=0$ wall. |
| Printing Controls | 1s |
| vpform | Variable printing form, for labelling of axes. i: integers used for axes, viz. (i,j,k) c: coordinates used for axes, viz. (x,y,z) |
| The printing controls and z direction. Only | which follothe x direction |
| vxp1,vxp2,vxp3, | Logicals for printing 'values' for pl,p2,p3, |

| vxz1,vxz2,vxz3, vxt,vxu,vxv,vxw | z1,z2,z3,t,u,v and w at the locations specified below. |
|---|--|
| <pre>mxp1, mxp2, mxp3, mxz1, mxz2, mxz3, mxt, mxu, mxv, mxw</pre> | Logicals for printing 'maps' for pl,p2,p3, z1,z2,z3,t,u,v and w at the locations specified below. |
| xc npx | Form of the x- printing planes specification. p: integer plane location [1,nx] c: coordinate plane location [0,arx] Number of printing planes to required. |
| mx (npx) or rmx (npx) | Print planes for values and maps (integer or real depending on xc). Values and maps are produced if logicals vx?? and mx?? = true. (Line may be repeated 'comment & data cards' if more than 11 planes are required.) (Note: If real location does not exist as a plane, next rounded up plane is used.) |
| residuals r rt,rpl,rp2,rp3, rmax | Logicals for printing residuals of t,pl,p2,p3. Logical for printing out only the maximum value and location of residuals. |
| divergences divv,divp dmax | Logicals for printing divergence of the velocity and vector potential fields. Logical for printing out only the maximum value and location of the divergences. |
| exprmnt | Name of the experiment, also used as file names for results output. |
| Heating Source | |
| npt noaram | Number of points of heating source data: Maximum value is 10, if npt < 10, say npt=6, tpnt(1) to tpnt(6) represent the temperature data and Q(1) to Q(6) represent respiration rates corresponding to each temperature point. |
| srcetype | ing source unit |
| tpnt(1) to tpnt(10) | Temperature points for heating source data. |
| Q(1) to Q(10) | Respiration rates at different temperature points. |
| numshow | Step for showing running results on monitor. |
| darcyx darcyy darcyz | Darcy number in x direction. Darcy number in y direction. Darcy number in z direction. |

datype Indication of values of Darcy number or ratios in
 x,y,z, directions:
 v or v: values
 R or r: ratio
 If datype=R or r, darcy is determine in subroutine
 SETCON and darcyx = darcyx * darcy,
 darcyy = darcyy * darcy,
 darcyz = darcyz * darcy.
gridfile File name for non-uniform grid.

END OF DATA FILE 'inparam'

gridfile (SAMPLE)

Sample 'gridfile' Grid Distrib File
NODAL DISTRIBUTION IN X-DIRECTION (STEPSIZE BETWEEN NODES (NX-1))
NUMBER OF MESH POINTS-NX =011 (REPEAT NEXT 2 LINES IF (NX-1) > 14}
*-1--**-2--**-3--**-4--**-5--**-6--**-7--**-8--**-9--**11--**12--**13--** NODAL DISTRIBUTION IN Y-DIRECTION (STEPSIZE BETWEEN NODES (NY-1))
NUMBER OF MESH POINTS-NY =013 (REPEAT NEXT 2 LINES IF (NY-1) > 14)
*-1--**-2--**-3--**-4--**-5--**-6--**-7--**-8--**-9--**10--**11--**12--**13--** NODAL DISTRIBUTION IN Z-DIRECTION (STEPSIZE BETWEEN NODES (NZ-1))

-1---2--**-3--**-4--**-5--**-6--**-7--**-8--**-9--**10--**11--**12--**13--** 20.00 52.00 52.00 52.00 68.00 68.00 68.00 68.00 52.00 52.00 50.00 20.00 20.00 28.00 36.00 36.00 36.00 36.00 28.00 20.00 20.00 20.00 20.00 32.00 44.00 44.00 44.00 44.00 32.00 20.00 20.00 END OF SAMPLE DATA FILE 'app_353' (contains 16 lines)