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THE COMPUTER PROGRAMS FOR HEAT TRANSFER ANALYSIS IN A HORIZONTAL ANNULAR POROUS INSULATION LAYER

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The Computer Programs for Heat Transfer Analysis in a Horizontal Annular Porous Insulation Layer

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Two computor programs have been developed to analyze natural convective heat transfer in an annular porous insulation layer which has a horizontal axis.

In the insulation layer, it is considered that the Darcy's law rules the fluid motion and the effect of density variation on natural convection is taken into account basis of Boussinesq approximation.

The boundary condition at the outer surface of insulation layer is applicable to both constant temperature and given heat transfer conditions for the energy equation. In solving the equations the successive over relaxation (SOR) method was employed for both momentum and energy equations and up-wind difference-method was also applied to the convective term of energy equation to avoid the divergence of the solutions.

The input data including some control parameters are briefly described with their formats and the output data are also explained.

Elements of the programs including the main program and the functions of subroutines are described.

The source program listing is appended.

Keywords: Hot Gas Duct, Natural Convection, Porous Media, High Temperature Thermal Insulation, Effective Thermal Conductivity, Boussinesq Approximation, SOR Method, Up-wind Difference

水平軸環状多孔質断熱層内の熱伝達解析プログラム

日本原子力研究所東海研究所高温工学部
下 村 寛 昭

（1984年1月31日受理）

水平軸，環状多孔質断熱層内の自然対流熱伝達解析を行う二種類の計算機プログラムを開発した。

これらプログラム中において，断熱層内の流体運動はDarcy法則を適用し，かつ，自然対流に及ぼす密度変化の影響はBoussinesq 近似を用いた。

断熱層の外面におけるエネルギー方程式に対する境界条件は大別して，一定温度の場合と種々の熱伝達条件に対する場合の両方が適用可能である。

運動方程式及びエネルギー方程式の数値解にあたっては繰返し過緩和法（SOR法）を適用し，また，エネルギー式の非線型項（対流項）については解の発散を避けるため，風上差分を適用した。

コントロールパラメータを含む入力データの意味，フォーマット及び出力データについて簡単な説明を加えた他，プログラムの各要素とそれぞれの機能についても述べ，ソースリストを附録とした。

Contents

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1. Introduction

In the field of high temperature gas-cooled reactor technology, high temperature gas duct whose inside is composed of fibrous thermal insulation layer has become very important technology from the technological standpoint.

The heat transfer under such high pressure atmosphere is characterized as follows:

(1) Grashof number (Gr) or Rayleigh number (Ra, a product of Grashof number and Prandth number Gr·Pr) increases approximately in proportion to the square of gas pressure because the kinematic viscosity and thermal diffusivity are proportional to the gas pressure.

(2) Heat transfer by natural convection in thermal insulation layer, total heat transferred across thermal insulation layer, and variation of effective thermal conductivity increases with Rayleigh number.

(3) Relative thermal expansion difference of insulation and a metal tube causes macroscopic gap in insulation layer. This gives rise to additional heat loss and local overheating of the pressure tube. It also affects material strength and stress of the duct.

(4) Radiation heat transfer in insulation layer increases near the high temperature surface.

(5) Mass transfer of gas impurities between fibrous insulation to flowing gas, and safety problems in rapid depressurization are important.

Few theoretical studies of previous problems have been published so far, because empirical thermal conduction model have been satisfactory for thermal design in atmospheric air. In empirical considerations, the "thermal conductivity" has been used not taking into account of the size of insulation layer, relative direction of the gravity force and the temperature difference across the layer. The "thermal conductivity" has been considered to be a physical property of the insulation materials.

In contrast to the studies mentioned above, present study on natural convective heat transfer in porous (fibrous) media has been carried out. Detailed theory and formulation have been already reported by the author.[1] The computor program for calculating the heat transfer of a hot gas duct will be briefly described in the following sections.

2. Basic Equations

As already reported in the preceding paper[1), following assumptions are applied to the momentum balance of fluid motion in the insulation layer:

(a) Darcy's law is applicable to the relation of pressure drop and interstitial velocity of fluid.

(b) The inertia term is negligible for the present case where a product of Rayleigh number and Darcy number, RaDa, is less than 10,000.

(c) Viscous shear force $\mu\nabla^2 u$ does not appear to be a reasonable term in a macroscopic treatment of the fluid motion in the porous media.

Heat conduction in the outer tube wall is taken into account where a temperature boundary condition at outer surface is not constant temperature.

2.1 Coordinate system

As shown in Fig. 2.1, both case which has and does not have outer wall two dimensional annular insulation layer with horizontal axis are studied in the present work.

In these systems, temperature and flow fields are assumed to be symmetric about a central vertical axis of both annular spaces.

2.2 Equation of fluid motion in the fibrous media

In the fibrous insulation materials the momentum balance for the fluid can be represented by Darcy's law which describes a linear relation between pressure drop and interstitial velocity of fluid as follows:

$$\frac{\nu\varepsilon}{K} u = -\frac{1}{\rho_\infty} \cdot \frac{\partial p}{\partial r} + \frac{\rho}{\rho_\infty} g \cos\phi \qquad (1)$$

$$\frac{\nu\varepsilon}{K} v = -\frac{1}{\rho_\infty r} \cdot \frac{\partial p}{\partial \phi} - \frac{\rho}{\rho_\infty} g \sin\phi \qquad (2)$$

where
- ρ : fluid density
- g : gravity acceleration coefficient
- p : pressure of fluid
- μ : kinematic viscosity of fluid
- K : permeability of insulation layer

u,v : interstitial velocity components in r and ϕ directions respectively

ε : porosity of insulation layer

In the equations, the physical properties of fluid and insulation materials are assumed to be constant except the case where fluid density change causes buoyancy (Bousinesque approximation). This assumption is generally employed in the analysis of natural convection.

2.3 Equation of continuity

In the coordinate system méntioned above, the equation of continúity can be described as follows:

$$\frac{\partial(ru)}{\partial r} + \frac{\partial v}{\partial \phi} = 0 \tag{3}$$

where r : radial coordinate

ϕ : azimuthal coordinate

The compressibility of gas is neglected in the equation. This approximation can be acceptable generally for natural convection.

2.4 Equation of energy

Energy equation is described as follows:

$$u\frac{\partial T}{\partial r} + \frac{v}{r}\frac{\partial T}{\partial \phi} = a_m\left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2}\right) \tag{4}$$

where T : temperature

a_m : effective thermal diffusivity of insulation layer

a_m is given by,

$$a_m = \lambda_m/(c_p \cdot \rho)_f$$

where λ_m : thermal conductivity of insulation layer in the case where natural convection is so weak that heat is transferred by conduction only

$(c_p \cdot \rho)_f$: heat capacity of fluid except fibrous material

2.5 Equation of thermal conduction

The equation of thermal conduction in a hot gas duct pressure wall is expressed by the following equation. When the temperature of the outer surface of hot gas duct is constant, this equation of thermal conduction is not used, because heat conduction in the pressure wall is negligible, but convergence of numerical computation takes long time.

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2} = 0 \qquad (5)$$

2.6 Boundary conditions

The boundary conditions for equation of energy or thermal conduction are given as,

$r = r_i$,

$$T = T_i \qquad (0 \leqq \phi \leqq \pi) \qquad (6)$$

$$u = 0 \qquad (0 \leqq \phi \leqq \pi) \qquad (7)$$

$r = r_o$,

$$u = 0 \qquad (0 \leqq \phi \leqq \pi) \qquad (8)$$

$$T_{in} = T_w \qquad (0 \leqq \phi \leqq \pi) \qquad (9)$$

$$\lambda_i \frac{\partial T}{\partial r} = \lambda_w \frac{\partial T_w}{\partial r} \qquad (0 \leqq \phi \leqq \pi) \qquad (10)$$

$r = r_w$,

$$-\frac{\partial T}{\partial r} = \frac{\alpha_o}{\lambda}(T - T_\infty) \qquad (0 \leqq \phi \leqq \pi) \qquad (11)$$

Flow and temperature fields are symmetrical about a vertical axis,

$\phi = 0,\ \phi = \pi,$

$$\frac{\partial T}{\partial \phi} = 0 \qquad (r_i \leqq r \leqq r_w) \qquad (12)$$

$$v = 0 \qquad (r_i \leqq r \leqq r_o) \qquad (13)$$

where r_i : inner radius of insulation

r_w : outer radius of hot gas duct

r_o : outer radius of insulation (radius of insulation and pressure wall interface)

λ : thermal conductivity

subscript i : insulation layer or inner radius

w : hot gas duct wall.

Change of fluid density is given by,

$$\rho = \rho_o \{1 - \beta(T - T_o)\} \quad . \tag{14}$$

2.7 Dimensionless expression of equation

Introducing a dimensionless stream function (ψ) defined by,

$$u = \frac{a_m}{r_i R} \frac{\partial \psi}{\partial \phi} \tag{15}$$

$$v = -\frac{a_m}{r_i} \frac{\partial \psi}{\partial R} \tag{16}$$

ψ satisfies Eq. (3). Then, Eqs. (1), (2), (4) and (5) are transformed into dimensionless forms to yield :

$$- \mathrm{RaDa} \left(\frac{\partial \theta}{\partial R} \sin \phi + \frac{1}{R} \frac{\partial \theta}{\partial \phi} \cos \phi \right) = \frac{\partial^2 \psi}{\partial R^2} + \frac{1}{R} \frac{\partial \psi}{\partial R} + \frac{1}{R^2} \frac{\partial^2 \psi}{\partial \phi^2} \tag{17}$$

$$\frac{\partial \psi}{\partial \phi} \cdot \frac{\partial \theta}{\partial R} - \frac{\partial \psi}{\partial R} \cdot \frac{\partial \theta}{\partial \phi} = R \left(\frac{\partial^2 \theta}{\partial R^2} + \frac{1}{R} \frac{\partial \theta}{\partial R} + \frac{1}{R^2} \frac{\partial^2 \theta}{\partial \phi^2} \right) \tag{18}$$

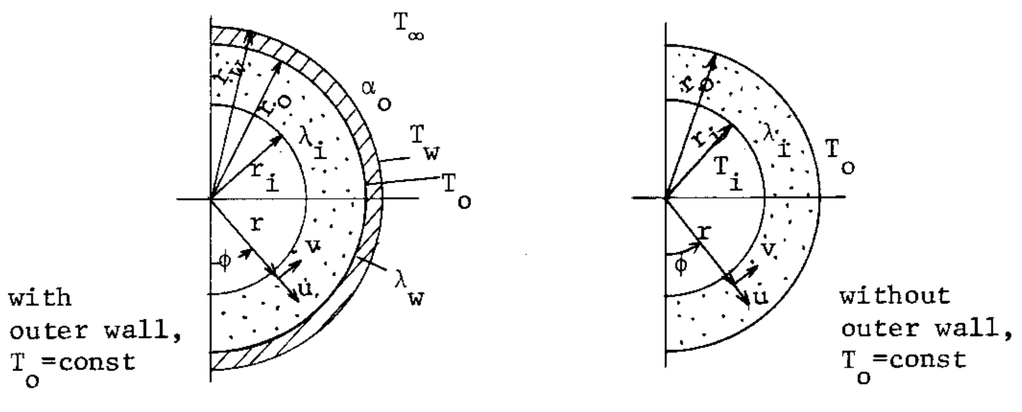

Fig. 2.1 Coordinate system

$$\frac{\partial^2\theta}{\partial^2 R} + \frac{1}{R}\frac{\partial\theta}{\partial R} + \frac{1}{R^2}\frac{\partial^2\theta}{\partial\phi^2} = 0 \tag{19}$$

where $R = r/r_i$

$\theta = (T - T_o)/(T_i - T_o)$

$R_a = g(T_i - T_o) \cdot r_i^3/(T_o \cdot a_m \cdot \nu \cdot \varepsilon)$

$D_a = K/r_i^2$

Boundary conditions (6) - (13) are made dimensionless to give:

at $R = 1$,

$$\theta = 1 \qquad (0 \leqq \phi \leqq \pi) \tag{20}$$

$$\frac{\partial\psi}{\partial\phi} = 0 \qquad (0 \leqq \phi \leqq \pi) \tag{21}$$

at $R = r_o/r_i$,

$$\frac{\partial\psi}{\partial\phi} = 0 \qquad (0 \leqq \phi \leqq \pi) \tag{22}$$

$$\theta_{i_{R=R_o}} = \theta_{w_{R=R_o}} \qquad (0 \leqq \phi \leqq \pi) \tag{23}$$

$$\lambda_i \left(\frac{\partial\theta}{\partial R}\right)_{R=R_o} = \lambda_w \left(\frac{\partial\theta}{\partial R}\right)_{R=R_o} \qquad (0 \leqq \phi \leqq \pi) \tag{24}$$

at $R = R_w$,

$$-\left(\frac{\partial\theta}{\partial R}\right)_{R=R_w} = Nu_w^* \,\theta \qquad (0 \leqq \phi \leqq \pi) \tag{25}$$

at $\phi = 0, \pi$,

$$\frac{\partial\theta}{\partial\phi} = 0 \qquad (1 < R < R_w) \tag{26}$$

$$\frac{\partial\psi}{\partial R} = 0 \qquad (1 < R < R_o) \tag{27}$$

where $$Nu_w^* = \frac{1}{2} Nu_o \,/\, \left(\frac{\lambda_w}{\lambda_\infty} R_w\right) \tag{28}$$

$$Nu_o = 2\,\alpha_o\, r_w / \lambda_\infty \tag{29}$$

$$R_o = r_o/r_i \quad , \quad R_w = r_w/r_i \tag{30}$$

It can be seen that solution of Eqs. (16) and (17) is determined uniquely by two parameters, RaDa and R_o ($= r_o/r_i$) .

Based on the logarithmic mean radius of the annular insulation layer, the relative increase of effective thermal conductivity caused by natural convection λ_e/λ (dimensionless effective thermal conductivity) is given by:

$$(\lambda_e/\lambda)_i = -(\partial\theta/\partial R)_{R=1} \, \ell n \, R_o \tag{31}$$

$$(\lambda_e/\lambda)_o = -(\partial\theta/\partial R)_{R=R_o} \, R_o \, \ell n \, R_o \tag{32}$$

The circumferential mean value of the dimensionless effective thermal conductivity $(\lambda_e/\lambda)_m$ is obtained as follows:

$$\begin{aligned}(\lambda_e/\lambda)_m &= -\frac{1}{\pi} \, \ell n \, R_o \int_o^{\pi} \left(\frac{\partial\theta}{\partial R}\right)_{R=1} d\phi \\ &= -\frac{R_o}{\pi} \, \ell n \, R_o \int_o^{\pi} \left(\frac{\partial\theta}{\partial R}\right)_{R=R_o} d\phi\end{aligned} \tag{33}$$

Ratio of local heat flux to its mean value (q/q_m) is given by,

$$(q/q_m)_\phi = \pi \left(\frac{\partial\theta}{\partial R}\right)_{R=1,R_o} \Big/ \int_o^{\pi} \left(\frac{\partial\theta}{\partial R}\right)_{R=1,R_o} d\phi \tag{34}$$

From the equation above, the dimensionless effective thermal conductivity $(\lambda_e/\lambda)_m$ is expressed by,

$$(\lambda_e/\lambda)_m = f \, (\, RaDa \, , \, R_o \,) \tag{35}$$

The function in Eq. (35) can be determined by solving Eqs. (17), (18) and (19) numerically under given boundary conditions.

3. Numerical Method

The flow pattern and temperature distribution in the insulation layer can be determined by solving Eqs. (17), (18) and (19) with boundary conditions (20) and (27).

Applying finite difference approximation, Eqs. (17) and (18) are transformed into (36) and (37) respectively.

In the transformation, the up-wind difference method was employed to avoid the numerical instability caused by nonlinear convection term of energy eq. (18).

$$\frac{1}{\partial R^2}(\psi_{i-1,j} - 2\psi_{i,j} + \psi_{i+1,j}) + \frac{1}{2R_i\delta R}(\psi_{i+1,j} - \psi_{i-1,j})$$

$$+ \frac{1}{(R_i\delta\phi)^2}(\psi_{i,j-1} - 2\psi_{i,j} + \psi_{i,j+1})$$

$$= - R_a D_a [(\theta_{i+1,j} - \theta_{i-1,j})\frac{\sin\phi_j}{2\delta R} + (\theta_{i,j+1} - \theta_{i,j-1})\frac{\cos\phi_j}{2R_i\delta\phi}] \qquad (36)$$

$$(\frac{\psi_{i,j+1} - \psi_{i,j-1}}{2\delta\phi})(\frac{\pm\theta_{i,j} \mp \theta_{i\mp1,j}}{\delta R}) - (\frac{\psi_{i+1,j} - \psi_{i-1,j}}{2\delta R})(\frac{\pm\theta_{i,j} \mp \theta_{i,j\mp1}}{\delta\phi})$$

$$= \frac{R_i}{\delta R^2}(\theta_{i+1,j} + \theta_{i-1,j} - 2\theta_{i,j}) + (\frac{\theta_{i+1,j} - \theta_{i,j}}{\delta R})$$

$$+ \frac{1}{R_i(\delta\phi)^2}(\theta_{i,j+1} + \theta_{i,j-1} - 2\theta_{i,j}) \qquad (37)$$

In the left term of eq. (37), finite difference of temperature is selected between the defined point and the up-wind mesh point of velocity U or V (i.e., $\frac{\partial\psi}{\partial\phi}$ or $-\frac{\partial\psi}{\partial\phi}$).

The equation of thermal conduction in the hot gas duct wall (19) is transformed into the following forms in each region,

at the contact interface between insulation layer and pressure wall ($R = R_o$),

$$(\frac{2R_k}{\delta R_i + \delta R_w})[\frac{\theta_{k-1,j}}{\delta R_i} + \frac{\lambda_w}{\lambda_i}\cdot\frac{\theta_{k+1,j}}{\delta R_w} - \theta_{k,j}(\frac{\lambda_w}{\lambda_i}\cdot\frac{1}{\delta R_w} + \frac{1}{\delta R_i})]$$

$$+ \frac{1}{2}[\theta_{k,j}(\frac{1}{\delta R_i} - \frac{\lambda_w}{\lambda_i}\cdot\frac{1}{\delta R_w}) + \frac{\lambda_w}{\lambda_i}\cdot\frac{\theta_{k+1,j}}{\delta R_w} - \frac{\theta_{k-1,j}}{\delta R_i}]$$

$$+\frac{\left(\dfrac{\delta R_i+\dfrac{\lambda_w}{\lambda_i}\cdot\delta R_w}{\delta R_i+\delta R_w}\right)}{R_k\cdot(\delta\phi)^2}(\theta_{k,j-1}+\theta_{k,j+1}-2\theta_{k,j})=0 \tag{38}$$

at $R = R_o$ to R_w ,

$$\frac{\theta_{i+1,j}+\theta_{i-1,j}-2\theta_{i,j}}{(\delta R_w)}+\frac{1}{R_i}\cdot\frac{\theta_{i+1,j}-\theta_{i-1,j}}{2\delta R_w}$$

$$+\frac{1}{R_i^2\cdot(\delta\phi)^2}(\theta_{i,j+1}+\theta_{i,j-1}-2\theta_{i,j})=0 \tag{39}$$

at $r = r_w$,

$$\frac{\theta_{M,j}-\theta_{M+1,j}}{\delta R_w}-\left(\frac{\lambda_\infty}{\lambda_w}\right)\cdot\frac{1}{2}Nu_o\cdot\frac{\theta_{M+1,j}}{R_w}$$

$$+\frac{\frac{1}{2}\delta R_w}{\left(R_w-\frac{\delta R_w}{4}\right)^2(\delta\phi)^2}(\theta_{M+1,j+1}+\theta_{M+1,j-1}-2\theta_{M+1,j})=0 \tag{40}$$

If the pressure wall is approximated in one radial mesh, Eq.(19) is written as follows:

$$\lambda_i\frac{\theta_{M,j}-\theta_{M+1,j}}{\delta R_w}-\lambda_\infty\cdot\frac{1}{2}Nu_o\cdot\frac{\theta_{M+1,j}}{R_w}$$

$$+\frac{\lambda_w}{(\delta\phi)^2}(\theta_{M+1,j+1}+\theta_{M+1,j-1}-2\theta_{M+1,j})\frac{R_w-R_o}{\{\frac{1}{2}(R_w+R_o)\}^2}=0 \tag{41}$$

In the beginning of solving the equation of fluid motion (36), the values of stream function ψ_{ij}'s are initially guessed to be zero at all mesh points, and for energy equation (37) and equation of heat conduction of hot gas duct wall (38) to (40) or (41), dimensionless temperature θ_{ij}'s are guessed to be 1 to 0 linearly from the inside to the outside of the insulation layer at all azimuthal mesh points.

After the initial guess, the stream function ψ_{ij}'s at all mesh points of equation (36) are calculated iteratively for a given temperatures distribution by the successive overrelaxation method (SOR). The iteration is continued until the convergence is achieved.

The dimensionless temperature θ_{ij}'s are calculated from the previously calculated stream function ψ_{ij}'s by the same way as the calculation of stream function.

These iterative calculation cycles of stream function and temperature are repeated alternatively until the stream function ψ_{ij} and temperature θ_{ij} of all mesh points satisfy the following conditions.

$$\left\{\begin{aligned}
&\left|\frac{\sum_{ij}(\psi_{ij})_n - \sum_{ij}(\psi_{ij})_{n-1}}{\sum_{ij}(\psi_{ij})n}\right| \leq E_1 && \text{(a)}\\
&\left|\frac{\sum_{ij}|(\theta_{ij})_n| - \sum_{ij}|(\theta_{ij})_{n-1}|}{\sum_{ij}(\theta_{ij})_n}\right| \leq E_1 && \text{(b)}\\
&\frac{1}{n+1}\sum_j\left|\frac{|(\theta_{M+1,j})_{n-1}| - |(\theta_{M+1,j})_n|}{|(\theta_{M+1,j})_n|}\right| \leq E_1 && \text{(c)}
\end{aligned}\right\} \quad (42)$$

where n : present iteration cycle

$n-1$: last iteration cycle

E_1 : allowable convergence error

$M+1$: radial mesh number at outer surface

When the boundary condition that the outer surface is cooled under a definite heat transfer coefficient is used, amendments of temperature in the iteration cycles become significantly large at the region near the outer surface. Therefore, Eq. (42)(c) becomes a convergence criteria of temperature for this boundary condition.

4. Outline of the Programs

Two computor programs are prepared to analyze the heat transfer characteristics of the thermal insulation layer mentioned in the preceding sections. The difference of these programs mainly lies in the boundary condition at the outer surface of the layer. In the first program, the boundary condition of constant temperature is taken, on the other hand, in the second one, the boundary conditions of constant temperature and heat transfer is taken, as shown in Table 5.1.

In the second program, thermal conduction in the outer wall (pressure tube) is taken into account.

5. Functions and Input Data of the Programs

Basically each program solves the same equations: An equation of energy in annular porous media with horizontal axis and an equation of motion, simultaneously in the same system.

Boundary conditions are applicable to each program in Table 5.1.

Table 5.1 Program names and boundary conditions

program name (file name)	boundary conditions on the outer surface of hot gas duct
NAPHAS3	uniform constant temperature. (heat transfer coefficient on the outer surface of the hot gas duct is large enough to establish uniform constant temperature.)
WALNAPH	a) uniform constant temperature. (results will be the same as those of NAPHAS3) b) given heat transfer conditions. * given uniform heat transfer coefficient. * given nonuniform heat transfer coefficient. * natural convective cooling by a given Rayleigh number.

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(A) NAPHAS3

(A-1) 1st card (5I10)

1	10 11	20 21	30 31	40 41	50
M	N	ITEL	MPRINT	NPRINT	

M : Number of radial mesh division. (M = 40 is recommended)

N : Number of circumferential mesh division. (N = 40 is recommended)

ITEL : Limit number of the maximum iteration cycle. (1000 to 5000 is recommended)

MPRINT : Number of radial mesh for output data. (10 to 20)

NPRINT : Number of azimuthal mesh for output data. (10 to 20)

(A-2) 2nd card (5F5.0)

1	5 6	10 11	15 16	20 21	25
RMAX	RADA	ERROR	EXOMEG	OMPSI	

RMAX : Ratio of outer to inner radius of insulation layer (r_o/r_i)

RADA : Product of Rayleigh number and Darcy number.

$(g(T_i - T_o)r_iK/T_oa_m \cdot \nu \cdot \varepsilon)$

where g : acceleration of gravity force. (9.8 m/s^2)

T_i : temperature at inner surface of layer. (deg.-K)

T_o : temperature at outer surface of layer. (deg.-K)

r_i : inner radius of layer. (m)

r_o : outer radius of layer. (m)

K : permeability of layer. (m^2)

a_m : thermal diffusivity of layer. (m^2/S)

$(=\lambda m/(cp \cdot \rho)_f)$

λ_m : thermal conductivity of layer in the case where natural convection is very weak. (Kcal/m.hr.deg.)

$(cp \cdot \rho)_f$: heat capacity of fluid. (Kcal/m^3·deg.)

ν : kinematic viscosity of fluid. (m^2/S)

ε : porosity of layer. (−)

ERROR : Allowable convergence error for dimensionless temperature.

$(1.0 \times 10^{-6}$ to $1.0 \times 10^{-5})$

EXOMEG : Relaxation factor given externally for calculation of energy equation. (1.0 to 1.8)

OMPSI : Relaxation factor for calculation of momentum equation. (1.0 to 1.8)

(A-3) 3rd card (20A1, A4, 6X, A4)

1 ... 20	21 ... 24	25 ... 29	30 ... 33	
CONT(1)-----CONT(20)	OPT	6X	(BCOUT)	

CONT(1): control datum, if CONT(1) = "A", relaxation factor (EXOMEG in 2nd card) is used. If CONT(1) = "A", (blank datum) the factor is conventionally decided in the program. ("A" is recommended)

CONT(2): If "A" is used, interpolated dimensionless temperature distribution at the designated mesh points by MPRINT and NPRINT in 1st card is printed.

CONT(3): If "A" is used, the stream function at the designated mesh points are printed in the same manner as above.

CONT(4): If "A" is used, the temperature distribution is displayed graphically in a rectangular space of the printing paper. If library function "IBTOD" is not available at the computor center, it is impossible. (In this case, blank datum should be used.)

CONT(5): If "A" is used, the flow pattern is displayed in the same manner.

CONT(6):
CONT(7): } "A" is usable only at JAERI's computor center, it must be blank. (see page 23, (12))

CONT(8): When "A" is given, the vorticity pattern is displayed in the same manner as CONT(4).

CONT(9): If "A" is used, the relative inertia force patterns are displayed in the same manner.

OPT : If "A" is given for any one of CONT(4) to CONT(9), the string data "SIMA" should be given.

BCOUT : not used

(B) WALNAPH

(B-1) 1st card (3I10)

1	1011	2021	30
M	N	ITEL	

M :: Number of radial mesh divisions. (M = 40 is recommended)

N :: Number of circumferential mesh divisions
(N = 40 is recommended)

ITEL : Limit number of maximum iteration cycles. (1000 to 5000 is recommended)

(B-2) 2nd card (7F5.0)

1	56	1011	1516	2021	2526	3031	35
RO	RADA	ERROR	ERRORP	EXOMEG	OMPSI	DOMMIN	

RO : Ratio of outer to inner radius of insulation layer. (r_0/r_1)

RADA : Product of Rayleigh number and Darcay number (see A-2)

ERROR : Allowable convergence error for dimensionless temperature. (recommended value = 1×10^{-5} to 1×10^{-6})

ERRORP : Allowable convergence error for calculation of stream function at every iteration cycle. (the same order as ERROR is recommended)

EXOMEG : Relaxation factor given externally for energy equation calculation. (1.0 to 1.8)

OMPSI : Relaxation factor for momentum equation calculation. (the same as above)

DOMMIN : Minimum adjusting width of relaxation factor, when automatic adjustment of relaxation factor is employed. (blank datum is recommended)

(B-3) 3rd card (20A1, A4)

1 — 20	21 — 24	
CONT(1)------CONT(20)	BCOUT	

CONT(1): Control datum, if "A" is used, EXOMEG in preceding card is used as a relaxation factor in the calculation of energy equation. ("A" is recommended)

CONT(2): When "A" is used, stream functions of all mesh points are printed, if not used, it is omitted.

CONT(3): Using "A", dimensionless radial velocity components are printed, it is omitted if another character is used.

CONT(4): Using "A", azimuthal velocity components are printed in the same manner as above.

CONT(5): Using "A", the temperature distribution is graphically displayed in the same way as CONT(4) of A-3.

CONT(6): Stream function is displayed as a substitute of the temperature in CONT(5).

CONT(7): } "A" is usable only in JAERI's computer center. (must be blank)
CONT(8): } (see page 23, (12))

BCOUT : Boundary condition at the outer surface of hot gas duct; if blank datum is used, uniform constant temperature condition is applied. (see Table 5.1, a)
If "ALPH" is used, given heat transfer condition is to be taken and the following data card must be added.

(B-4) 4th card (3F5.0, I5, A4)

1 — 5	6 — 10	11 — 15	16 — 20	21 — 24	
RW	TCWBYI	TCWBYO	MW	DIST	

RW : Ratio of pressure tube outer radius to inner radius of insulation layer. (r_w/r_i)

TCWBYI : Ratio of thermal conductivity of pressure tube to that of insulation layer in the case of natural convection in the layer is very weak. (λ_w/λ_i)

TCWBYO : Ratio of the thermal conductivity of pressure tube to that of air. (λ_w/λ_{air})

MW : Number of radial mesh divisions in pressure tube wall. (MW = 1 is recommended)

DIST : Heat transfer condition at the outer surface of pressure tube. (see Table 5.1, b)

If "CONS" is used, constant heat transfer coefficient is defined and the value of the Nusselt number (Nu_o) must be given by next card. If a blank datum is used, heat transfer coefficient of natural convection is defined, the value of Rayleigh number (Ra_o) must be given by the next card. In this case, heat transfer coefficient around the pressure tube is not uniform.

where $Nu_o = \alpha_0 D_w / \lambda_{air}$

$Ra_o = g(T_w - T_{air})\, D_w^3 / (T_{air} \cdot a_{air} \cdot \nu_{air})$

α_0 : heat transfer coefficient around pressure tube ($kcal/m^2 \cdot hr \cdot deg.$)

D_w : outer diameter of hot gas duct pressure tube (m)

λ_{air}: thermal conductivity of air ($kcal/m \cdot hr \cdot deg.$)

g : acceleration factor of gravity force ($9.8\ m/s^2$)

T_w : temperature of hot duct pressure tube surface (deg-K) (must be assumed)

T_{air}: temperature of surrounding air (deg-K)

a_{air}: thermal diffusivity of air (m^2/s)

ν_{air}: kinematic viscosity of air (m^2/s)

(B-5) 5th card (F10.0)

1 — 10	
RAO	

or

1 — 10	
AVNU	

RAO : Rayleigh number (Ra_0) defined in the preceding section, it must be given when a blank datum is used as "DIST" in the previous card.

AVNU : Nusselt number must be given, when "CONS" is used as "DIST" (constant heat transfer coefficient) in the previous card.

6. Output Data

Output data of the two programs are given in the almost same format, and are classified into six criteria as follows:

(a) input data
(b) information of iteration cycles and conditions of final convergence
(c) converged dimensionless temperature and stream function
(d) another data obtained from (c)
(e) summarized data
(f) graphical display

The important data in these criteria are briefly described in the following subsections.

6.1 Input data

The input data given from the cards previously described are printed in the same format. After calling a library subroutine DATAON, input data are printed when READ statement is executed.

In the case when the library subroutine DATAON is not available at the computer center, CALL DATAON statement preceded by READ statement must be deleted.

6.2 Information of iteration cycles

At the end of every iteration cycle of energy equation calculation, the following information is printed out.

ITER : Iteration number for energy equation.

ITEP : Iteration number for momentum equation at every one iteration cycle of energy equation calculation.

APS : Temperature variation error of all mesh points between the cycle and preceding one.

RAO : Rayleigh number (Ra_0) defined in the preceding section, it must be given when a blank datum is used as "DIST" in the previous card.

AVNU : Nusselt number must be given, when "CONS" is used as "DIST" (constant heat transfer coefficient) in the previous card.

6. Output Data

Output data of the two programs are given in the almost same format, and are classified into six criteria as follows:

(a) input data
(b) information of iteration cycles and conditions of final convergence
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6.2 Information of iteration cycles

At the end of every iteration cycle of energy equation calculation, the following information is printed out.

ITER : Iteration number for energy equation.

ITEP : Iteration number for momentum equation at every one iteration cycle of energy equation calculation.

APS : Temperature variation error of all mesh points between the cycle and preceding one.

ERRPSI : Error at the time when momentum equation is converged.

OMEGA : Relaxation factor for energy equation calculation.

OMPSI : Relaxation factor for momentum equation calculation.

EPSTW : Temperature variation error of outer surface mesh of the hot gas duct between adjoining iteration cycles.

6.3 Converged dimensionless temperature and stream function

The numerical solutions of energy and momentum equation, namely dimensionless temperature and stream function at all mesh points defined by I, J are printed.

The mesh numbers I and J define the position in the coordinates shown in Fig. 6.1.

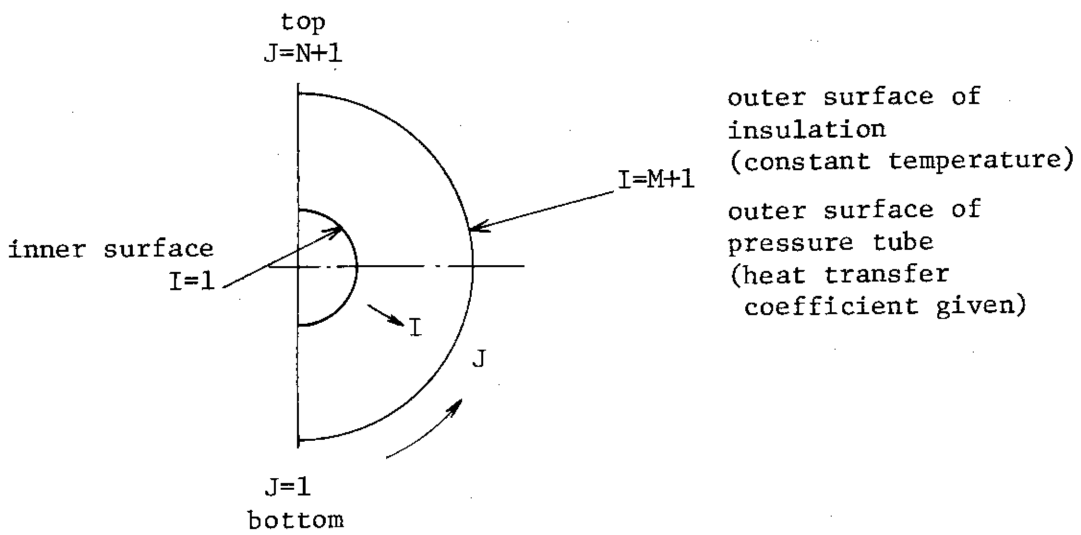


Fig. 6.1 Mesh numbers in the coordinate system

The reduced printing mesh number is applicable to avoid complication from numerous mesh points. (only for NAPHAS3)

6.4 Another data

Dimensionless radial (U) and azimuthal (V) velocity components are obtained from the stream function data. U and V are defined by,

$$u = (a_m/r_i R)\cdot U$$

$$v = (a_m/r_i)\cdot V$$

where u : absolute radial velocity component (m/s)
v : absolute azimuthal velocity component (m/s)

The vorticity and inertia data are also obtained from the stream function data.

6.5 Summarized data

The relative thermal conductivities ($\lambda_e(\phi)/\lambda_0$) and relative heat fluxes along the inner and outer surfaces are summarized from the data of dimensionless temperature. Data captions are defined as,

KE/K : $\lambda_e(\phi)/\lambda_0$

AVNUSS : $(\lambda_e(\phi)/\lambda_0)_{mean}$ at inner surface

AVNUSO : $(\lambda_e(\phi)/\lambda_0)_{mean}$ at outer surface

Q(J)/QM : $q(\phi)/q_m$

where $\lambda_e(\phi)$: effective thermal conductivity at azimuth ϕ in the case where natural convection is taken into account.

λ_0 : thermal conductivity in the case where natural convection is negligible.

$$(\lambda_e(\phi)/\lambda_0)_{mean} = \frac{1}{\pi\cdot\lambda_0}\int_0^{\pi}\lambda_e(\phi)d\phi$$

$q(\phi)$: local heat flux at azimuth ϕ

q_m : average heat flux ($= \frac{1}{\pi}\int_0^{\pi} q(\phi)d\phi$)

6.6 Graphical display

Temperature distribution and the other data are to be shown graphically. The coordinate system is depicted in a rectangular form as shown in Fig. 6.2.

The input data must be set up specially for the library subroutine IBTOD. (see CONT(3), (4), (5), (8), (8) of NAPHAS 3 and CONT(5), (6) of WALNAPH) If this subroutine is not available at the computer center, it is impossible to display the results.

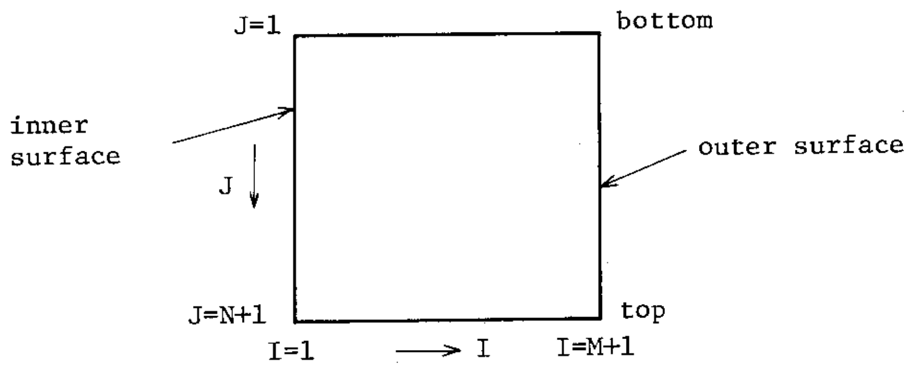


Fig. 6.2 Graphical coordinate system

7. Elements of the Programs

7.1 Main program

Basically, the main programs of the both programs are to control input data and arrange some subroutines which solve equations and output the results on a printer or magnetic disks.

7.2 Subroutines

(1) DATAON

This subroutine does not include in the source program but in the system library.

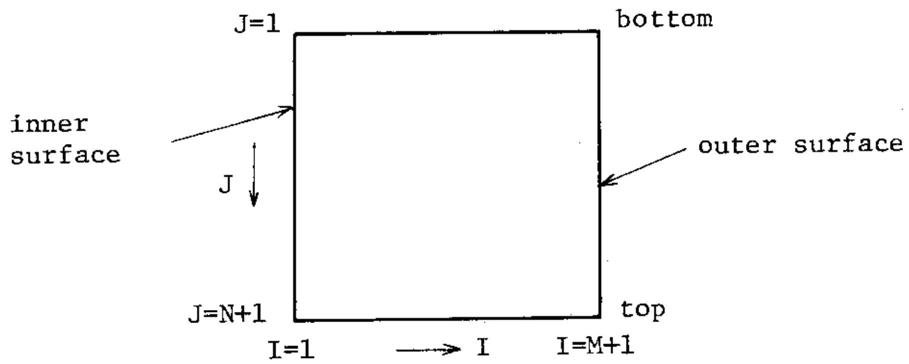
This subroutine has a simple function to print all input data after READ statement is executed. Therefore, if this subroutine is not available in the system, "CALL DATAON" must be deleted.

(2) VELOCI

This subroutine calculates for printing and solving the energy equation by the up-wind methods to get radial and circumferential velocity components U and V.

Both velocity components U and V are simply calculated by the following equation:

of WALNAPH) If this subroutine is not available at the computer center, it is impossible to display the results.



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This subroutine calculates for printing and solving the energy equation by the up-wind methods to get radial and circumferential velocity components U and V.

Both velocity components U and V are simply calculated by the following equation:

$$U = \frac{1}{R}\frac{\partial\psi}{\partial R} \tag{43}$$

$$V = -\frac{\partial\psi}{\partial R} \tag{44}$$

where R : dimensionless radial coordinate (= r/r_{in}) dimensionless

ψ : stream function (PSI)

This subroutine is called in the subroutine SIMSOL.

(3) PSISOL

This subroutine is called in the subroutine SIMSOL and uses SOR method to solve equation of natural convection motion of gas in the system.

Iteration cycles are continued until the convergence is achieved. If number of iteration cycles over a certain limit (ITEL, this value is given from input data), the calculation will be stopped and a message "PSI DOES NOT CONVERGE IN PSISOL" will be printed out. If

$$\frac{\sum_i(\psi_i)_{new} - \sum_i(\psi_i)_{old}}{\sum_i(\psi_i)_{new}} < \text{ERRORP} \tag{45}$$

is achieved, calculation returns to a subroutine SIMSOL.

(4) SIMSOL

The equation of energy and fluid motion in the system are solved simultaneously by this subroutine. At the first step of this subroutine, the equation of motion is solved for a given temperature distribution by calling a subroutine PSISOL, and then velocity components are calculated to solve the energy equation by SOR method by the up-wind technique.

Various boundary conditions for the energy equation can be treated in this subroutine. Thermal conduction in the outer wall (pressure tube) is also computed in this subroutine when the input data are given. In this subroutine, iteration cycles are continued until the convergence is achieved. At the end of every ten iteration cycles, some information on convergence is printed. (IAERA, ITEP ----- etc.)

In general, acceleration parameter or relaxation factor (OMEGA) in SOR method is very important and the appropriate selection of factors is rather difficult.

The most conservative value for acceleration parameter is 1.00.

(5) SIMPSN

This subroutine integrates local effective thermal conductivities of thermal insulation in both inner and outer walls of the hot gas duct by means of Simpson's method. After integrating these values, they are averaged through the circumference of inner or outer wall.

(6) HERMAN

The natural convective heat transfer coefficient of the horizontal cylinder which has uniform temperature was obtained by Hermann[2)] and improved by Spallow[3)].

This subroutine calculates heat transfer coefficient distribution around the hot gas duct using the above results.

Exactly speaking, this method of calculation is applicable only for a horizontal cylinder with uniform temperature, but the actual temperature distribution of hot gas duct outer wall is not always uniform.

For a practical use, however, the temperature distribution of hot gas duct can be taken as uniform, because the temperature variation on the actual hot gas duct surface is generally not so large.

This subroutine is applicable to the case when a hot gas duct surface is cooled by natural convection of air, and the average heat transfer coefficient around a hot gas duct is calculated by the following formula,

$$Nu = 0.399\ (Gr \cdot Pr)^{0.25} \qquad (46)$$

The outer diameter of the hot gas duct must be taken as a hydraulic diameter.

(7) VISUAL

This subroutine is prepared to print out the two dimensional matrix data (3 dimensional data) to get information on the calculated results.

(8) INTPL2

This subroutine interpolates one-dimensional array data by a second order interpolation, and is used in the subroutine D2ITPL.

(9) D2ITPL

This subroutine interpolates two-dimensional array data by the INTPL2. This is used in the subroutine VISUAL to transform the calculated data into the desired matrix size.

(10) OPTOM

The basic idea of this subroutine is that if divergence is occurred in the SOR iteration process, the value of an acceleration factor is decreased by a given step width. On the contrary, if not occurred, the factor is increased.

The adjusting step width is decreased step by step and the final value is used hereafter.

(11) PTSNGL

Double precision values are transformed into single precision value by this subroutine. It is only used to print out the result briefly.

(12) PLDATA

This subroutine transforms the Cartesian coordinate system into the polar coordinate one, normalizes the value and writes the data in a disk file which provides to plot contour line (iso-thermal line, stream line, etc.) by means of a contour line plotting program prepared in JAERI's program library (JGPCP). If the contour line plotting program is not provided in a computer library, this subroutine must not be called in the main program by using blank control data. (see page 13, 15)

(13) TABLE

This subroutine prints out two-dimensional matrix data with some titles on a line printer. Parameter in this subroutine "XLETER" is character data to be printed. Each element of the dimension (A(1), A(2)) allows 4 characters maximum, if hoped.

8. Conclusions

The following conclusions have derived from execusions of the programs.

(1) Convergence of numerical solutions and stability of the computations were successfully obtained when the relaxation factor (acceleration

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8. Conclusions

The following conclusions have derived from execusions of the programs.

(1) Convergence of numerical solutions and stability of the computations were successfully obtained when the relaxation factor (acceleration

factor) for the energy equation ranges from 1.0 to 1.1 to any practical value of RaDa.

(2) Using the value of relaxation factor from 1.0 to 1.8, convergence of the computations were so rapid when the value of RaDa does not exceed certain value and ratio of outer to inner radius lies from 1.2 to 2.0.

(3) Allowable value of convergence judgement E1 in eq. (42) is recommended as less than 1×10^{-6}.

(4) The appropriateness of the boundary conditions on the basis of symmetry against vertical axis for the temperature and flow pattern shown by eqs. (26) and (27) respectively is open to the further study.

When the natural convection is strong, symmetry of temperature and flow patterns against vertical axis may be not always maintained.

The author wishes to express cordial appreciation to Prof. T. Masuoka, Kyushu Institute of Technology, and also to Dr. H. Kawamura, Dr. K. Sanokawa and Dr. Y. Okamoto for their helpful advice and suggestion.

9. Literatures

1) Shimomura, H., et al.; Heat Transf. Japanese Research 8, 2, pp.1 - 11 (1979).
2) Hermann, R.; VDI Vorschungsheft, 379, B-7, pp.1 - 24 (1936).
3) Spallow, E.M. and Tsou, F.K.; Phys. Fluids, 8, 8 pp.1559 - 1561 (1965).

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Appendix

Source Program Listing

(1) WALNAPH

(2) NAPHAS3

(1) FACOM OSIV/F4 FORTRAN IV (HE)   V04L18   DATE 83.01.26 TIME 14.48.59

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

```
C         WALNAPH              JUL.  1977              BY H.SHIMOMURA
C      THIS PROGRAM COMPUTES THERMAL AND FLUID-DYNAMIC PERFORMANCES IN
C      HORIZONTAL ANNULAR POROUS SPACES IN GRAVITATIONAL FIELD.
C
C      REFERECE DOCUMENTATION   JAERI-M-
C
C      VARIABLES DEFINITION
C
C      RADA           RAYLEIGH NUMBER * DARCY NUMBER
C      AVNU           AVERAGE NUSSELT NUMBER AROUND WALL
C      WNU(J)         LOCAL NUSSELT NUMBER AROUND WALL
C      RAO            RAYLEIGH NUMBER AROUND WALL OUT SIDE
C      TCWBYI         THERMAL CONDUCTIVITY RATIO OF WALL TO INSULATION
C      TCWBYO         THERMAL CONDUCTIVITY RATIO OF WALL TO OUTER GAS
C      RO             D-LESS OUTER RADIUS OF INSULATION LAYER
C      RW             D-LESS OUTER RADIUS OF WALL
C      PHMAX          MAX.ANGULAR ARGUMENT FROM BOTTOM CENTER (=3.14..)
C      RI(I)          D-LESS RADIAL ARGUMENT (INNER RADIUS  =1)
C      PHI(J)         ANGULAR ARGUMENT
C      DR             ACTUAL RADIAL MESH WIDTH IN COMPUTATION
C      DRI            RADIAL MESH WIDTH FOR WALLED BC IN INS. =(RO-1)/KW-1
C      DRW            RADIAL MESH WIDTH FOR WALLED BC IN WALL =(RW-RO)/MW
C      DRT            RADIAL MESH WIDTH FOR T=CONST BC  =(RO-1)/M
C      DPH            ANGULAR MESH WIDTH
C      M              NUMBER OF RADIAL DIVISION
C      N              NUMBER OF ANGULAR DIVISION
C      MCAL           M+1
C      NCAL           N+1
C      MW             NUMBER OF RADIAL DIVISION IN WALL
C      KW             RADIAL MESH POINT AT INSULATION-WALL CONTACT
C
C
C      TN(I,J)        D-LESS TEMPERATURE AT ITERATION CYCLE ITERA
C      PSI(I,J)       D-LESS STREAM FUNCTION AT ITERATION CYCLE ITERA
C      U(I,J)         D-LESS RADIAL VELOCITY
C      V(I,J)         D-LESS ANGULAR VELOCITY
C      DTDRI(J)       D-LESS RADIAL TEMP. GRADIENT AT R=1.0
C      DTDRO(J)       D-LESS RADIAL TEMP. GRADIENT AT R=RO
C      EKBYK(J)       RATIO OF EFFECTIVE AND MOLEC. T.CONDUCT. AT R=1.0
C      EKBYKO(J)      RATIO OF EFFECTIVE AND MOLEC. T.CONDUCT. AT R=RO
C      AVNUSS         AVERAGE NUSSELT NUMBER AT R=1.0
C      AVNUSO         AVERAGE NUSSELT NUMBER AT R=RO
C      QIBYQM(J)      RELATIVE LOCAL HEAT FLUX AT INNER WALL(HEAT T COEFF)
C                     = ((KE/K)LOCAL)/((KE/K)AV.) AT R=1.0
C      QOBYQM(J)      RELATIVE LOCAL HEAT FLUX AT OUTER WALL(HEAT.T COEFF)
C                     = ((KE/K)LOCAL)/((KE/K)AV.) AT R=RO
C      ITERA          NUMBER OF ITERATION CYCLE
C      ITEL           LIMITED NUMBER OF ITERATION
C      OMEGA          RELAXATION FACTOR FOR ENERGY EQ.
C      EXOMEG         RELAXATION FACTOR GIVEN EXTERNALLY FOR ENERGY EQ.
C      OMPSI          RELAXATION FACTOR FOR EQ. OF MOTION
C      SNEW           SUMMATION OF TN(I,J) AT ITERATION CYCLE=N
C      SOLD           SUMMATION OF TN(I,J) AT ITERATION CYCLE=N-1
C      APS            SUMMATION OF ALL GRID POINTS RELATIVE TEMP. CHANGE
C      EPSTW          SUMMATION OF RELATIVE WALL TEMP. CHANGE
C      ERROR          ALLOWABLE CALCULATION ERROR FOR TN(I,J)
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18                DATE 83.01.26  TIME 14.48.59

                C      ERRORP          ALLOWABLE CALCULATION ERROR FOR PSI(I,J)
                C      KALP,BCOUT      IF BCOUT.EQ.ALPHBC(='ALPH') KALP=1, THEN DATA CARD
                C                      FOR (RW,TCWBYI,TCWBYO,AVNU,MW,DIST) MUST BE GIVEN
                C      DIST            IF DIST.EQ.CONS ('CONS'),WNU(J)=AVNU,KDIST=0
                C                      IF DIST.NE.CONS,  HERMAN,S THEORY IS APLLIED FOR
                C                      WNU(J), KDIST=1
                C      CONT(I)         OPTION CONTROLLER (I=1,2, ...,20)
                C      CONT(1) = 'A';EXTERNAL OMEGA IS USED, IF CONT(1).NE.'A',AUTOMATIC.
                C      CONT(2).NE.'A':PSI(I,J) PRINTING OMITTED
                C      CONT(3).NE.'A':U(I,J) PRINTING OMITTED
                C      CONT(4).NE.'A':V(I,J) PRINTING OMITTED
                C      CONT(5) = 'A';GRAPHIC TEMPERATUR DISTRIBUTION IS PRINTED
                C      CONT(6) = 'A';GRAPHIC FLOW PATTERN IS PRINTED
                C      CONT(7) = 'A';DATA FOR ISO-THERMAL LINE PLOTTING ARE OUTPUT IN
                C                      DISK FILE. (CONTROL CARDS ARE NECESSARY)
                C      CONT(8) = 'A';DATA FOR STREAM LINE PLOTTING ARE OUTPUT IN
                C                      DISK FILE. (CONTROL CARDS ARE NECESSARY)
                C
                C
                C
ISN 00001              COMMON/INDEP/ RI(41),PHI(41),DR,DRT,DRI,DRW,DPH
ISN 00002              COMMON/TPUVC/ TN(41,41),PSI(41,41),U(41,41),V(41,41)
ISN 00003              COMMON/PARAC/ RO,RW,PHIMAX,RADA
ISN 00004              COMMON/INTEC/ M,N,MCAL,NCAL,MW,KW,KALP,KDIST
ISN 00005              COMMON/SORCO/ OMEGA,OMPSI,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,
                      1              ERRORP
ISN 00006              COMMON/SORCA/ SNEW,SOLD,EPSTW
ISN 00007              COMMON/WALLC/ WNU(41),AVNU,TCWBYI,TCWBYO,RAO
ISN 00008              COMMON/SCOMM/ TNS(41,41),PSIS(41,41)
ISN 00009              COMMON/CONCO/ CONT(80)
ISN 00010              COMMON/COMOPT/IOMEGA,DOM,NSIGN,TOLD(41,41),TRACER,DOMMIN
                C
ISN 00011              DIMENSION XX(50),YY(50),ZZ(50,50),ZYJ(41),ZIIJ(50,41),ZII(41),
                      1          EKBYK(41),DTDRO(41),EKBYKO(41),DTDRI(41),KZ(50,50),
                      2          QIBYQM(41),QOBYQM(41),TWPHI(41)
ISN 00012              DIMENSION TLETER(2),PLETER(2),ULETER(2),VLETER(2)
ISN 00013              DIMENSION TOPHI(41)
                C
ISN 00014              DOUBLE PRECISION TN,PSI
ISN 00015              DOUBLE PRECISION TOLD
ISN 00016              DATA CONS,CP,CN,ALPHBC/'CONS','A',' ','ALPH'/
ISN 00017              DATA (TLETER(I),I=1,2)/' TEM','P.'/
ISN 00018              DATA (PLETER(I),I=1,2)/'  PS','I '/
ISN 00019              DATA (ULETER(I),I=1,2)/'U(I,',',J)'/
ISN 00020              DATA (VLETER(I),I=1,2)/'V(I,',',J)'/
ISN 00021              PHMAX = 3.1415926
                C         ***** INITIALIZATION *****
ISN 00022              KW = 1
ISN 00023              DRI  =  1.
ISN 00024              DRW  =  1.
ISN 00025              CALL DATAON
                C
ISN 00026              READ (5,1) M,N,ITEL
ISN 00027              MCAL = M+1
ISN 00028              NCAL = N+1
ISN 00029              READ (5,2) RO,RADA,ERROR,ERRORP,EXOMEG,OMPSI,DOMMIN
ISN 00030              READ (5,3) (CONT(K),K=1,20),BCOUT
                C
ISN 00031              IF (BCOUT.EQ.ALPHBC) GO TO 10
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        MAIN  DATE 83.01.26  TIME 14.48.59

  ISN 00032              KALP=0
  ISN 00033              GO TO 520
  ISN 00034           10 KALP=1
  ISN 00035              READ (5,11) RW,TCWBYI,TCWBYO,MW,DIST
  ISN 00036              IF(RW.LE.RO)      GO  TO    900
  ISN 00037              IF((MW.GT.M).OR.(MW.LT.O))       GO  TO     950
  ISN 00038              KW =M+1-MW
  ISN 00039              IF (DIST.EQ.CONS) GO TO 510
                   C         VARIABLE NUSSELT
  ISN 00040              KDIST = 1
  ISN 00041              READ (5,12) RAO
  ISN 00042              GO TO 520
                   C
                   C         CONSTANT NUSSELT
  ISN 00043          510 READ (5,12) AVNU
  ISN 00044              KDIST = 0
  ISN 00045              DO 515 J=1,N+1
  ISN 00046          515 WNU(J) = AVNU
                   C
  ISN 00047          520 IF (CONT(1).EQ.CP) OMEGA = EXOMEG
                   C
                   C                    MESH SIZE
  ISN 00048              DPH = PHMAX/N
                   C
                   C                    OUTER BOUNDARY CONDITION DETECTION
  ISN 00049              IF (BCOUT.EQ.ALPHBC) GO TO 6
  ISN 00050              DRT = (RO-1.0)/M
  ISN 00051              DO 540 I=1,M+1
  ISN 00052          540 RI(I) = DRT*(I-1)+1.0
  ISN 00053              GO TO 550
  ISN 00054            6 DRI = (RO-1.0)/(KW-1)
  ISN 00055              IF (MW.GE.1) DRW = (RW-RO)/MW
  ISN 00056              IF (MW.EQ.0) DRW = RW-RO
                   C
  ISN 00057              RI(1) = 1.0
  ISN 00058              DO 8 I=2,M+1
  ISN 00059              IF (I.GT.KW) GO TO 7
  ISN 00060              DR = DRI
  ISN 00061              GO TO 8
  ISN 00062            7 DR = DRW
  ISN 00063            8 RI(I) = RI(I-1)+DR
                   C
                   C
  ISN 00064          550 DO 560 J=1,N+1
  ISN 00065          560 PHI(J) = DPH*(J-1)
  ISN 00066              ITERA = 0
  ISN 00067              ITERB = 0
  ISN 00068              IF (KALP.EQ.1.AND.KDIST.EQ.1) CALL HERMAN
                   C         INITIAL SET AND BOUNDARY CONDITIONS
  ISN 00069              IF (KALP.EQ.1) GO TO 564
                   C         INITIAL SET FOR T = CONSTANT
  ISN 00070              DO 562 J=1,N+1
  ISN 00071              DO 562 I=1,M+1
  ISN 00072          562 TN(I,J) = (RO-RI(I))/(RO-1.0)
  ISN 00073              GO TO 571
                   C         INITIAL SET FOR WALLED
  ISN 00074          564 DO 570 J=1,N+1
  ISN 00075              WNUST1 = 0.5*WNU(J)*TCWBYI/(RW*TCWBYO)
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        MAIN  DATE 83.01.26  TIME 14.48.59

  ISN 00076          WNUST2 = 0.5*WNU(J)/(RW*TCWBYO)
  ISN 00077          REX1 = RO+(RW-RO)/TCWBYI+1.0/WNUST1
  ISN 00078          REX2 = RW+1.0/WNUST2
  ISN 00079          DO 570 I=1,M+1
  ISN 00080          IF (I.GT.KW) GO TO 566
               C          R . LE . RO
  ISN 00081          TN(I,J) = (REX1-RI(I))/(REX1-1.0)
  ISN 00082          GO TO 570
               C          R . GT . RO
  ISN 00083      566 TN(I,J) = TN(KW,J)*(REX2-RI(I))/(REX2-RO)
  ISN 00084      570 CONTINUE
  ISN 00085      571 DO 572 J=1,N+1
  ISN 00086          DO 572 I=1,M+1
  ISN 00087      572 PSI(I,J) = 0.0
  ISN 00088          IOMEGA = 0
               C
  ISN 00089       40 SOLD  =  0.
  ISN 00090          SNEW  =  0.
  ISN 00091          EPSTW  =  0.
  ISN 00092          IF (CONT(1).EQ.CP) GO TO 50
               C                     OMEGA OPTIMIZATION
  ISN 00093          CALL OPTOM
               C
  ISN 00094       50 CALL SIMSOL
  ISN 00095          IF((NSIGN.EQ.-1).AND.(CONT(1).EQ.CP))      GO  TO   1000
  ISN 00096          IF(NSIGN.EQ.-1)      GO TO 40
               C
  ISN 00097          ESP=(SNEW-SOLD)/SNEW
  ISN 00098          APS = ABS(EPS)
  ISN 00099          IF (KALP.EQ.1) GO TO 55
  ISN 00100          IF(APS.LE.ERROR) GO TO 75
  ISN 00101          GO TO 60
  ISN 00102       55 IF (APS.LE.ERROR.AND.EPSTW.LE.ERROR) GO TO 75
  ISN 00103       60 IF (ITERA.LE.ITEL) GO TO 70
               C                     *** LATEST DATA OUTPUT ***
  ISN 00104          PRINT 65, ITERA,OMEGA,EPS
  ISN 00105          GO TO 80
               C
  ISN 00106       70 ITERA = ITERA+1
  ISN 00107          ITERB = ITERB+1
  ISN 00108          IF (ITERB.LT.10) GO TO 40
  ISN 00109          PRINT 240, ITERA,ITEP,EPS,ERRPSI,OMEGA,OMPSI
  ISN 00110          IF (KALP.EQ.1) PRINT 245,EPSTW
  ISN 00111          ITERB = 0
  ISN 00112          GO TO 40
               C
               C
  ISN 00113       75 PRINT 230, ITERA,ITEP,EPS,ERRPSI
  ISN 00114       80 IF (KALP.EQ.1) PRINT 235, EPSTW
  ISN 00115          CALL VELOCI
  ISN 00116          CALL PTSNGL
               C
                     CALL TABLE(TNS,TLETER)
  ISN 00117          IF(CONT(2).NE.CP)      GO  TO  81
  ISN 00118          CALL TABLE(PSIS,PLETER)
  ISN 00119                  U(I,J)  PRINT  OUT
               C
               C
  ISN 00120       81 IF(CONT(3).NE.CP)      GO  TO   83
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        MAIN  DATE 83.01.26  TIME 14.48.59

  ISN 00121          CALL   TABLE(U,ULETER)
                C
                C
  ISN 00122       83 IF(CONT(4).NE.CP)       GO  TO  85
  ISN 00123          CALL  TABLE(V,VLETER)
                C
                C
                C
                C
                C
                C
                C
  ISN 00124       85 CONTINUE
                C
                C                       MEAN WALL T. AND T. DIFFERENCE
  ISN 00125          IF (KALP.EQ.0) GO TO 320
  ISN 00126      300 DO 310 J=1,N+1
  ISN 00127      310 TOPHI(J) = TN(KW,J)
  ISN 00128          CALL SIMPSN (N+1,DPH,TOPHI,TROM,IEE)
  ISN 00129          TROM = TROM/PHMAX
  ISN 00130          DTOIN = 1.0-TROM
  ISN 00131          GO TO 330
  ISN 00132      320 DTOIN = 1.0
  ISN 00133      330 CONTINUE
                C                       EFFECTIVE AND MOLECULAR CONDUCTIVITY RATIO
                C
  ISN 00134          DO 90 J=1,N+1
  ISN 00135          DTDRI(J) = (-25.*TN(1,J)+48.*TN(2,J)-36.*TN(3,J)+16.*TN(4,J)
                   1           -3.*TN(5,J))/(12.*DR)
  ISN 00136          EKBYK(J) = -DTDRI(J)*ALOG(RO)/DTOIN
  ISN 00137          IF(KALP.EQ.1) GO TO 360
                C         CONSTANT TEMPERATURE
  ISN 00138          MO = M
  ISN 00139          DR = DRT
  ISN 00140          GO TO 370
                C         H.T. COEFF B.C. (WALLED)
  ISN 00141      360 MO = KW-1
  ISN 00142          DR = DRI
                C
  ISN 00143      370 DTDRO(J) = (25.0*TN(MO+1,J)-48.0*TN(MO,J)+36.0*TN(MO-1,J)
                   1        -16.0*TN(MO-2,J)+3.0*TN(MO-3,J))/(12.0*DR)
  ISN 00144       90 EKBYKO(J) = -DTDRO(J)*RO*ALOG(RO)/DTOIN
  ISN 00145          CALL   SIMPSN (N+1,DPH,EKBYK,SEKBYK,IER1)
  ISN 00146          CALL   SIMPSN (N+1,DPH,EKBYKO,SEKBKO,IER)
  ISN 00147          AVNUSS = SEKBYK/3.1415926
  ISN 00148          AVNUSO = SEKBKO/3.1415926
                C
  ISN 00149          PRINT 111, AVNUSS,RADA, RO
  ISN 00150          PRINT 121, (J,EKBYK(J), J=1,N+1)
                C
  ISN 00151          PRINT 115, AVNUSO,RADA,RO
  ISN 00152          PRINT 121, (J,EKBYKO(J), J=1,N+1 )
                C                       RELATIVE LOCAL HEAT FLUX
                C
  ISN 00153          DO 98 J=1,N+1
  ISN 00154          QIBYQM(J) = EKBYK(J) /AVNUSS
  ISN 00155       98 QOBYQM(J) = EKBYKO(J)/AVNUSO
                C
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        MAIN  DATE 83.01.26  TIME 14.48.59

ISN 00156           PRINT 122
ISN 00157           PRINT 121, (J,QIBYQM(J), J=1,N+1)
ISN 00158           PRINT 123
ISN 00159           PRINT 121, (J,QOBYQM(J), J=1,N+1)
              C
ISN 00160           IF (KALP.EQ.1) GO TO 100
ISN 00161           GO TO 130
ISN 00162       100 DO 91 J=1,N+1
ISN 00163        91  TWPHI(J) = TN(M+1,J)
ISN 00164           CALL SIMPSN (N+1,DPH,TWPHI,STW,IER)
ISN 00165           TWM = STW/3.1415926
ISN 00166           PRINT 400, AVNU,TWM
ISN 00167           IF (KDIST.EQ.0) GO TO 120
              C                      *** NUSSELT VARIABLE ***
ISN 00168           PRINT 410
ISN 00169           PRINT 430, (J,WNU(J),J=1,N+1)
              C
ISN 00170       120 PRINT 420
ISN 00171           PRINT 430, (J, TN(M+1,J), J=1,N+1 )
ISN 00172           PRINT 440, TROM
ISN 00173           PRINT 430, (J,TOPHI(J),J=1,N+1)
ISN 00174       130 CONTINUE
ISN 00175           IF (CONT(5).NE.CP) GO TO 241
ISN 00176           CALL VISUAL (RI,PHI,TNS,M+1,N+1,XX,YY,ZZ,ZYJ,ZIIJ,ZII,KZ)
ISN 00177           PRINT 250
ISN 00178       241 CONTINUE
ISN 00179           IF (CONT(6).NE.CP) GO TO 243
              C
ISN 00180           CALL VISUAL (RI,PHI,PSIS,M+1,N+1,XX,YY,ZZ,ZYJ,ZIIJ,ZII,KZ)
ISN 00181           PRINT 260
ISN 00182       243 CONTINUE
ISN 00183           IF (CONT(7).NE.CP) GO TO 270
ISN 00184           RR = RO
ISN 00185           IF (KALP.EQ.1) RR=RW
ISN 00186           CALL PLDATA   (RI,PHI, TNS,M+1,N+1,RR)
ISN 00187       270 CONTINUE
              C
ISN 00188           IF (CONT(8).NE.CP) GO TO 280
ISN 00189           RR = RO
ISN 00190           IF (KALP.EQ.1) RR=RW
ISN 00191           CALL PLDATA    (RI,PHI,PSIS,M+1,N+1,RR)
ISN 00192       280 CONTINUE
              C                      INPUT FORMATS
ISN 00193         1 FORMAT (3I10)
ISN 00194         2 FORMAT ( 7F5.0 )
ISN 00195         3 FORMAT (20A1,A4)
              C
ISN 00196        11 FORMAT (3F5.0,I5,A4)
ISN 00197        12 FORMAT ( F10.0 )
              C                      ALARM MESSAGES
ISN 00198        65 FORMAT ('1', // T20,'CONVERGENCE OF TN(I,J) ARE NOT ACHIEVED' /
                 1                  T20,' NUMBER OF ITERATION(ITERA) =', I6, /
                 2                  T20,' RESULTS AFTER LATEST ITERATION ARE AS FLLOWS
                 3'/T20, ' OMEGA =', 1PE13.4/ T20, 'EPS  =', 1PE13.4 /)
              C
              C                      OUTPUT FORMATS
ISN 00199       111 FORMAT ( '1' // T47,  'EFFECTIVE CONDUCTIVITY ON INNER WALL'
                 A                // T20, 'AVNUSS = ', 1PE15.3, T50,'RADA = ',1PE15.3,
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18       MAIN  DATE 83.01.26  TIME 14.48.59
                    1                   T80, 'RO = ', 1PE15.3 // T5, 9( 'J',4X,'KE/K',
                    2                   5X )  / )
  ISN 00200       115 FORMAT (    /// T47,  'EFFECTIVE CONDUCTIVITY ON OUTER SURFACE (RO)
                    A',               // T20, 'AVNUSO = ', 1PE15.3, T50,'RADA = ',1PE15.3,
                    1                   T80, 'RO = ', 1PE15.3 // T5, 9( 'J',4X,'KE/K',
                    2                   5X )  / )
                C
  ISN 00201       121 FORMAT ( 9(I6,    F8.4 ) /)
  ISN 00202       122 FORMAT (// T46, 'RELATIVE LOCAL HEAT FLUX AT INNER WALL' //
                    1               T5,  9( 'J', 3X, 'Q(J)/QM',    3X)  / )
  ISN 00203       123 FORMAT (// T46, 'RELATIVE LOCAL HEAT FLUX AT OUTER WALL' //
                    1               T5,  9( 'J', 3X, 'Q(J)/QM',    3X)  / )
  ISN 00204       230 FORMAT ( '1',//  T20, ' TN(I,J) AND PSI(I,J) ARE CONVERGED.', //
                    1                  T20, ' ITERA = ',  I4,  T50, '(TEMP-LOOP)',
                    2               /  T20, ' ITEP = ',  I4,  T50,  '(PSI-LOOP)',
                    3               /  T20,    '    EPS   = ', 1PE13.4,T50, '(TEMP ERROR)',
                    4               /  T20,  ' ERRPSI= ', 1PE13.4,T50, '(PSI-ERROR)'/ )
  ISN 00205       235 FORMAT (  T20, ' EPSTW = ', 1PE13.4, T50, '(T-WALL ERROR)' )
  ISN 00206       240 FORMAT (  T2,  'ITERA =', I4,  T16, 'ITEP =', I4, T29,
                    1            'EPS =',1PE11.4, T49, 'ERRPSI =', 1PE11.4,
                    2            T71,  'OMEGA =', 1PE11.4, T93,  'OMPSI =', 1PE11.4 )
  ISN 00207       245 FORMAT ('+', T114, 'EPSTW = ',1PE11.3     )
                C
  ISN 00208       250 FORMAT (///T47, ' NORMALIZED TEMPERATURE DISTRIBUTION ' )
  ISN 00209       260 FORMAT (///T45, ' NORMALIZED STREAM FUNCTION DISTRIBUTION ')
                C
  ISN 00210       400 FORMAT ( '1', //// T20, 'OUT SIDE NUSSELT NO (AVNU)  =',1PE11.3,
                    1          /// T20, 'D-LESS MEAN WALL TEMP (TWM) =',1PE11.3 // )
  ISN 00211       410 FORMAT ( /// T45, 'NUSSELT NUMBER AROUND WALL OUT SIDE', //
                    1              T5,  9( 'J', 3X,' WNU(J)',   3X ) /)
  ISN 00212       420 FORMAT (//T37,'D-LESS TEMPERATURE DISTRIBUTION AROUND WALL OUT SID
                    1E' //         T5,  9( 'J', 2X, 'TN(M+1,J)', 2X ) / )
  ISN 00213       430 FORMAT (  9( I6, F8.4 ) / )
                C
  ISN 00214       440 FORMAT (    //// T20, 'AVERAGE CONTACT SURFACE TEMP. (TROM) =',
                    1  1PE11.4 //// T37, 'D-LESS TEMPERATURE DISTRIBUTION AROUND CONTAC
                    2T SURFACE',//  T5, 9( 'J', 2X,'TOPHI(J)', 3X   )/ )
  ISN 00215       900 WRITE(6,460)
  ISN 00216       460 FORMAT('    ***RW (WALL  OUTER  R. )  IS  TOO  SMALL ***')
  ISN 00217           GO  TO   1100
  ISN 00218       950 WRITE(6,470)
  ISN 00219       470 FORMAT('***  MW (RADIAL  DIY.  OF  WALL ) ERROR *****  ')
  ISN 00220           GO  TO   1100
  ISN 00221      1000 WRITE(6,480)
  ISN 00222       480 FORMAT('      TN(I,J)      ABNORMAL       *****')
  ISN 00223      1100 STOP
  ISN 00224           END
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.26  TIME 14.49.01

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001            SUBROUTINE VELOCI
                 C
                 C
                 C
  ISN 00002            COMMON/INDEP/ RI(41),PHI(41),DR,DRT,DRI,DRW,DPH
  ISN 00003            COMMON/TPUVC/ TN(41,41),PSI(41,41),U(41,41),V(41,41)
  ISN 00004            COMMON/INTEC/ M,N,MCAL,NCAL,MW,KW,KALP,KDIST
  ISN 00005            DOUBLE PRECISION TN,PSI
                 C
  ISN 00006            DR = DRT
  ISN 00007            IF (KALP.EQ.1) DR = DRI
                 C
  ISN 00008            DO 10 J=1,N+1
  ISN 00009            DO 10 I=1,M+1
  ISN 00010            IF (J.EQ.1)   GO TO 1
  ISN 00011            IF (J.EQ.N+1) GO TO 2
  ISN 00012            U(I,J) = (PSI(I,J+1)-PSI(I,J-1)) / (2.0*RI(I)*DPH)
  ISN 00013            GO TO 3
                 C
  ISN 00014          1 U(I,J) = (PSI(I,J+1)-PSI(I,J)) / (RI(I)*DPH)
  ISN 00015            GO TO 3
                 C
  ISN 00016          2 U(I,J) = (PSI(I,J)-PSI(I,J-1)) / (RI(I)*DPH)
                 C
  ISN 00017          3 IF (I.EQ.1)   GO TO 4
  ISN 00018            IF (I.EQ.M+1) GO TO 5
  ISN 00019            V(I,J) = (PSI(I-1,J)-PSI(I+1,J)) / (2.0*DR)
  ISN 00020            GO TO 10
                 C
  ISN 00021          4 V(I,J) = (PSI(I,J)-PSI(I+1,J)) / DR
  ISN 00022            GO TO 10
  ISN 00023          5 V(I,J) = (PSI(I-1,J)-PSI(I,J)) / DR
  ISN 00024         10 CONTINUE
  ISN 00025            RETURN
  ISN 00026            END
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.26  TIME 14.49.01

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001            SUBROUTINE PSISOL
                 C
                 C     THIS ROUTINE SOLVES EQ. OF MOTION IN HORIZONTAL ANNULAR POROUS
                 C     MEDIA BY EXTRAPOLATED LIEBMANN METHOD
                 C                                   REVISED ON MARCH 1978
                 C        TN         DIMENSIONLESS TEMPERATURE AT MESH POINTS (I,J)
                 C        PSI        DIMENSIONLESS STREAM FUNCTION AT MESH POINTS (I,J)
                 C        OMPSI      RELAXATION FACTOR     '
                 C
  ISN 00002            COMMON/INTEC/ M,N,MCAL,NCAL,MW,KW,KALP,KDIST
  ISN 00003            COMMON/SORCO/ OMEGA,OMPSI,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,
                     1               ERRORP
  ISN 00004            COMMON/PARAC/ RO,RW,PHIMAX,RADA
  ISN 00005            COMMON/TPUVC/ TN(41,41),PSI(41,41),U(41,41),V(41,41)
  ISN 00006            COMMON/INDEP/ RI(41),PHI(41),DR,DRT,DRI,DRW,DPH
  ISN 00007            DOUBLE PRECISION TN,PSI
                 C
                 C
  ISN 00008            IF (KALP.EQ.1) GO TO 2
                 C                   T = CONSTANT
  ISN 00009            MSOL = M
  ISN 00010            DR = DRT
  ISN 00011            GO TO 3
                 C
                 C                   WALLED
  ISN 00012          2 MSOL = KW-1
  ISN 00013            DR = DRI
                 C
                 C
  ISN 00014          3 ITEP = 0
                 C
                 C
  ISN 00015          5 SPSI = 0.
  ISN 00016            SPSIO= 0.
                 C
  ISN 00017            DO 10 J=2,N
  ISN 00018            DO 10 I=2,MSOL
  ISN 00019            A = 2.0/DR**2 + 2.0/(RI(I)*DPH)**2
  ISN 00020            B = (PSI(I+1,J)+PSI(I-1,J))/DR**2
  ISN 00021            C = (PSI(I+1,J) - PSI(I-1,J))/(2.0*RI(I)*DR)
  ISN 00022            D = (PSI(I,J+1)+PSI(I,J-1))/(RI(I)*DPH)**2
  ISN 00023            E = (TN(I+1,J)-TN(I-1,J))/(2.0*DR)*SIN(PHI(J))
  ISN 00024            F = (TN(I,J+1)-TN(I,J-1))/(2.0*RI(I)*DPH)*COS(PHI(J))
                 C
  ISN 00025            SPSIO = SPSIO+PSI(I,J)
  ISN 00026            PSI(I,J) = (1.0-OMPSI)*PSI(I,J)+OMPSI/A*(B+C+D+RADA*(E+F))
  ISN 00027         10 SPSI = SPSI + PSI(I,J)
                 C
  ISN 00028            ITEP = ITEP+1
  ISN 00029            ERRPSI = ABS((SPSI-SPSIO)/SPSI)
  ISN 00030            IF (ITEP.GT.ITEL) GO TO 20
  ISN 00031            IF (ERRPSI.LT.ERRORP) GO TO 30
                 C
  ISN 00032            GO TO 5
                 C
  ISN 00033         20 PRINT 100, ITERA,ITEP,ERRPSI,EPS
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      PSISOL  DATE 83.01.26  TIME 14.49.01

               C
               C
  ISN 00034            STOP
  ISN 00035         30 RETURN
               C
  ISN 00036        100 FORMAT ( '1' // T20, ' PSI DOES NOT CONVERGE IN PSISOL '  //
                  1                   T20, ' ITERA= ', I4,      T50, '(TEMP-LOOP)'
                  2                 / T20, ' ITEP = ', I4,      T50, '(PSI-LOOP) '
                  3                 / T20, 'ERRPSI= ', 1PE13.4, T50, '(PSI-ERROR)'
                  4                 / T20, '  EPS = ', 1PE13.4, T50, '(TEMP-ERROR)'/ )
               C
  ISN 00037            END
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.26  TIME 14.49.03

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

ISN 00001              SUBROUTINE SIMSOL
                 C
                 C     THIS ROUTINE SOLVES ENERGY AND MOTIONAL EQ. SIMULTANEOUSLY IN
                 C     HORIZONTAL ANNULAR POROUS MEDIA BY SUCCESSIVE OVER RELAXATION
                 C     METHOD WITH UPPER STREAM DIFFERENTIAL TECHNIQUE.
                 C
                 C        TN          DIMENSIONLESS TEMPERATURE AT MESH POINTS (I,J)
                 C        PSI         DIMENSIONLESS STREAM FUNCTION AT MESH POINTS (I,J)
                 C        OMEGA       RELAXATION FACTOR
                 C        U           DIMENSIONLESS RADIAL VELOCITY COMPONENT AT (I,J)
                 C        V           DIMENSIONLESS CIRCUMFERENTIAL VELOCITY COMPONENTS
                 C                    AT (I,J)
                 C        RO          D-LESS RADIUS FOR INSULATION-WALL CONTACT RO=RI(KW)
                 C        RW          D-LESS RADIUS FOR WALL OUTER SURFACE RW=RI(M+1)
                 C        RI(I)       D-LESS RADIUS  I=1,...KW,...M,M+1
                 C        PHI(J)      ANGLE FROM BOTTOM CENTER  J=1,...N,N+1  (RAD)
                 C        DR          RADIAL MESH WIDTH AT RI(I)
                 C        DRT         RADIAL MESH WIDTH IN INSULATION FOR T=CONST B.C.
                 C                                                    DRT=(RO-1.0)/M
                 C        DRI         RADIAL MESH WIDTH IN INSULATION FOR WALLED B.C.
                 C                                                    DRI=(RO-1.0)/(KW-1)
                 C        DRW         RADIAL MESH WIDTH IN WALL FOR WALLED B.C.
                 C                                                    DRW=(RW-RO)/MW
                 C        DPH         ANGULAR MESH WIDTH    DPH=3.14.../N
                 C        KW          RADIAL MESH POINT NUMBER FOR INS.-WALL CONTACT
                 C        MW          NUMBER OF RADIAL DIVISION IN WALL
                 C        M           NUMBER OF RADIAL DIVISION IN INSULATION AND WALL
                 C        N           NUMBER OF ANGULAR DIVISION  (  DPH=3.14.../N  )
                 C        TCWBYI      RATIO OF WALL TO INS. T-CONDUCTIVITY
                 C        TCWBYO      RATIO OF WALL TO WALL OUT SIDE GAS T-CONDUCTIVITY
                 C        WNU(J)      NUSSELT NUMBER AROUND WALL OUT SIDE  J=1,...N+1
                 C        KALP        KEY FOR OUT SIDE BOUNDARY CONDITION KALP=0; T=CONST
                 C                                                    KALP=1; WALLED
                 C
                 C
ISN 00002              COMMON/INTEC/ M,N,MCAL,NCAL,MW,KW,KALP,KDIST
ISN 00003              COMMON/SORCO/ OMEGA,OMPSI,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,
                      1              ERRORP
ISN 00004              COMMON/SORCA/ SNEW,SOLD,EPSTW
ISN 00005              COMMON/PARAC/ RO,RW,PHIMAX,RADA
ISN 00006              COMMON/TPUVC/ TN(41,41),PSI(41,41),U(41,41),V(41,41)
ISN 00007              COMMON/INDEP/ RI(41),PHI(41),DR,DRT,DRI,DRW,DPH
ISN 00008              COMMON/WALLC/ WNU(41),AVNU,TCWBYI,TCWBYO,RAO
ISN 00009              COMMON/COMOPT/ IOMEGA,DOM,NSIGN,TOLD(41,41),TRACER,DOMMIN
ISN 00010              DOUBLE PRECISION   TOLD
ISN 00011              DOUBLE PRECISION TN,PSI
                 C
ISN 00012              CALL PSISOL
                 C                    DIMENSIONLESS VELOCITY
ISN 00013              CALL VELOCI
                 C
ISN 00014              IF (KALP.EQ.1) GO TO 2
ISN 00015              MLAST = M
ISN 00016              DR = DRT
ISN 00017              GO TO 3
ISN 00018            2 DR = DRI
ISN 00019              AA = 2*RO/(DRI+DRW)*(TCWBYI/DRW+1.0/DRI)
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      SIMSOL  DATE 83.01.26  TIME 14.49.03

ISN 00020            BB = 0.5*(TCWBYI/DRW-1.0/DRI)
ISN 00021            A1 = (DRI+TCWBYI*DRW)/(DRI+DRW)
ISN 00022            CC = 2*A1/(RO*DPH**2)
ISN 00023            MLAST = M+1
ISN 00024            TNW1 = 2.0*TN(M+1,2)
ISN 00025            TNWN = 2.0*TN(M+1,N)
ISN 00026            RMW = 0.5*(RO+RW)
ISN 00027            CONST1 = TCWBYI*(RW-RO)/RMW**2
               C
ISN 00028          3 DO 91 J=1,N+1
ISN 00029            IF (KALP.EQ.1) TWOLD = TN(M+1,J)
ISN 00030            DO 90 I=2,MLAST
ISN 00031            SOLD = SOLD + TN(I,J)
ISN 00032            TO=TN(I,J)
ISN 00033            IF (KALP.EQ.0) GO TO 5
               C
               C          WALLED OUTER SURFACE
ISN 00034          4 IF (I.EQ.M+1) GO TO 71
ISN 00035            IF (I.GE.KW+1) GO TO 11
ISN 00036            IF (I.EQ.KW)   GO TO 72
               C
               C
ISN 00037            GO TO 5
ISN 00038         11 CONTINUE
ISN 00039            A = 2.0*RI(I)/DRW**2 + 2.0/(RI(I)*DPH**2)
ISN 00040            B = RI(I)*(TN(I+1,J) + TN(I-1,J))/DRW**2
ISN 00041            C = (TN(I+1,J)-TN(I-1,J))/(2.0*DRW)
ISN 00042            IF (J.GT.1.AND.J.LT.N+1)  D=(TN(I,J+1)+TN(I,J-1))/(RI(I)*DPH**2)
ISN 00043            IF (J.EQ.1) D = TN(I,2)/(RI(I)*DPH**2)*2
ISN 00044            IF (J.EQ.N+1) D = TN(I,N)/(RI(I)*DPH**2)*2
ISN 00045            E = 0.0
ISN 00046            F = 0.0
ISN 00047            GO TO 25
               C
               C          CONSTANT T. OR WALLED (I.NE.KW,  I.NE.KW+1, I.NE.M+1)
ISN 00048          5 CONTINUE
               C
ISN 00049            IF (U(I,J).GT.0.0) GO TO 10
ISN 00050            A = -U(I,J)/DR*RI(I)
ISN 00051            E = -U(I,J)*TN(I+1,J)/DR*RI(I)
ISN 00052            GO TO 20
               C
ISN 00053         10 A = U(I,J)/DR*RI(I)
ISN 00054            E = U(I,J)*TN(I-1,J)/DR*RI(I)
               C
ISN 00055         20 IF (V(I,J).GT.0.0) GO TO 30
ISN 00056            A = A - V(I,J)/DPH
ISN 00057            IF (J.GT.1.AND.J.LT.N+1) F = -V(I,J)*TN(I,J+1)/DPH
ISN 00058            GO TO 40
               C
ISN 00059         30 A = A + V(I,J)/DPH
ISN 00060            IF (J.GT.1.AND.J.LT.N+1) F = V(I,J)*TN(I,J-1)/DPH
               C
ISN 00061         40 A = A + 2.0*RI(I)/DR**2 + 1.0/DR + 2.0/(RI(I)*DPH**2)
               C
ISN 00062            B = RI(I)*(TN(I+1,J)+TN(I-1,J))/DR**2
               C
ISN 00063            C = TN(I+1,J)/DR
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      SIMSOL  DATE 83.01.26  TIME 14.49.03

                      C
  ISN 00064                 IF (J.EQ.1)   GO TO 50
  ISN 00065                 IF (J.EQ.N+1) GO TO 60
  ISN 00066                 D = (TN(I,J+1)+TN(I,J-1))/(RI(I)*DPH**2)
  ISN 00067                 GO TO 70
                      C
  ISN 00068              50 D = 2.0*TN(I,2)/(RI(I)*DPH**2)
  ISN 00069                 GO TO 70
                      C
  ISN 00070              60 D = 2.0*TN(I,N)/(RI(I)*DPH**2)
                      C
  ISN 00071              70 IF (J.EQ.1.OR.J.EQ.N+1) F = 0.0
                      C
                      C
  ISN 00072              25 TN(I,J) = (1.0-OMEGA)*TN(I,J) + OMEGA/A*(B+C+D+E+F)
                      C
  ISN 00073                 GO TO 85
                      C
                      C                         TEMP AT R=RW   ( I=M+1 )
  ISN 00074              71 IF (MW.EQ.0) GO TO 1000
  ISN 00075                 IF (J.GT.1.AND.J.LT.N+1)  TNJJ=TN(M+1,J+1)+TN(M+1,J-1)
  ISN 00076                 IF (J.EQ.1)               TNJJ=TNW1
  ISN 00077                 IF (J.EQ.N+1)             TNJJ=TNWN
                      C
  ISN 00078                 TN(M+1,J) = TN(M,J)/DRW+0.5*TNJJ*DRW/((RW-DRW/4)*DPH)**2
  ISN 00079                 TN(M+1,J) = TN(M+1,J)/(1.0/DRW + 0.5*WNU(J)/(TCWBYO*RW)
                           1            + DRW/((RW-DRW/4)*DPH)**2)
  ISN 00080                 GO TO 85
                      C
                      C                         SINGLE WALL LAYER MODEL ( MW = 0 )
  ISN 00081            1000 IF (J.GT.1.AND.J.LT.N+1)  TNJJ=TN(M+1,J+1) + TN(M+1,J-1)
  ISN 00082                 IF (J.EQ.1)               TNJJ=TNW1
  ISN 00083                 IF (J.EQ.N+1)             TNJJ=TNWN
  ISN 00084                 WNUSTI = 0.5*WNU(J)*TCWBYI/(RW*TCWBYO)
  ISN 00085                 TN(M+1,J) = (TN(M,J)/DRI + CONST1*TNJJ/DPH**2) /
                           1            (1.0/DRI + WNUSTI + 2.0*CONST1/DPH**2)
  ISN 00086                 GO TO 85
                      C
                      C                         TEMP AT R=RO   ( I=KW )
  ISN 00087              72 DD = 2*RO/(DRI+DRW)*(TN(KW-1,J)/DRI+TCWBYI*TN(KW+1,J)/DRW)
  ISN 00088                 EE = 0.5*(TCWBYI*TN(KW+1,J)/DRW-TN(KW-1,J)/DRI)
  ISN 00089                 IF (J.EQ.1)   GO TO 73
  ISN 00090                 IF (J.EQ.N+1) GO TO 74
  ISN 00091                 FF = A1*(TN(KW,J+1)+TN(KW,J-1))/(RO*DPH**2)
  ISN 00092                 GO TO 75
                      C                         J = 1
  ISN 00093              73 FF = 2*A1*TN(KW,2)/(RO*DPH**2)
  ISN 00094                 GO TO 75
                      C                         J = N+1
  ISN 00095              74 FF = 2*A1*TN(KW,N)/(RO*DPH**2)
  ISN 00096              75 TN(KW,J) = (1.0-OMEGA)*TN(KW,J) + OMEGA/(AA+BB+CC)*(DD+EE+FF)
  ISN 00097                 GO TO 85
                      C
                      C
  ISN 00098              85 IF (TN(I,J).LT.0.0)  GO TO 86
  ISN 00099                 GO TO 90
                      C
                      C                         ABNORMAL TEMPERATURE INFORMATION
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      SIMSOL  DATE 83.01.26  TIME 14.49.03

 ISN 00100        86 IF (KALP.EQ.1.AND.I.EQ.KW) GO TO 87
 ISN 00101           PRINT 100, I,J,TN(I,J),A,B,C,D,E,F
 ISN 00102           X=TO*(1.0-OMEGA)
 ISN 00103           Y=OMEGA/A*(B+C+D+E+F)
 ISN 00104           PRINT 200, X,Y,TO,ITERA
 ISN 00105           GO TO 88
 ISN 00106        87 AB1 = (1.-OMEGA)*TO
 ISN 00107           AB2 = OMEGA/(AA+BB+CC)*(DD+EE+FF)
 ISN 00108           PRINT 300,I,J,TN(KW-1,J),TO,TN(KW,J),TN(KW+1,J),AA,BB,CC,DD,EE,
                   1              FF,AB1,AB2
 ISN 00109        88 NSIGN = -1
 ISN 00110           RETURN
                C
 ISN 00111        90 SNEW = SNEW + TN(I,J)
 ISN 00112           IF (KALP.EQ.1) EPSTW = DABS((TWOLD-TN(M+1,J))/TN(M+1,J))+EPSTW
 ISN 00113        91 CONTINUE
 ISN 00114           NSIGN = 1
 ISN 00115           IF (KALP.EQ.1) EPSTW = EPSTW/(N+1)
 ISN 00116           RETURN
                C                        INFORMATION FORMATS
 ISN 00117       100 FORMAT ( /    T8, 'I=', I2, '  J=', I2, '  TN=', 1PD11.3, '  A=',
                   1         1PD11.3, '  B=', 1PD11.3, '  C=', 1PD11.3, '  D=',1PD11.3,
                   2          '  E=', 1PD11.3, '  F=', 1PD11.3  )
                C
 ISN 00118       200 FORMAT (   T8,'(1.0-OMEGA)*TO = ',1PE13.3,T50,'OMEGA/A*(B+C+D+E+F)
                   1 = ', 1PE13.3, T90, 'TO =',1PE13.3, T110, 'ITERA=',I3 )
                C
 ISN 00119       300 FORMAT (   / T5,'I=',I3,5X,'J=',I3 , 5X, 'TN(KW-1,J) =', 1PE13.3,
                   1     5X, 'TO(KW,J) =', 1PE13.3, 5X,'TN(KW,J) =', 1PE13.3, 5X,
                   2     'TN(KW+1,J) =', 1PE13.3, //T10, 'AA', T21, 'BB', T32, 'CC',
                   3     T43, 'DD', T54, 'EE', T65, 'FF' /1P6E13.3//
                   4     T5, '(1.-OMEGA)*TO(KW,J) =', 1PE13.3, 5X, 'OMEGA/(AA+BB+CC) *
                   5(DD+EE+FF) =', 1PE13.3 //)
                C
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.26  TIME 14.49.06

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001              SUBROUTINE SIMPSN  (M,H,F,S,IER)
                   C
                   C         THIS ROUTINE INTEGRATES GIVEN FUNCTION F(1),F(2),...F(M) BY
                   C         SIMPSON METHOD.
                   C
                   C         M          NUMBER OF MESH POINTS  (M MUST BE ODD NUMBER)
                   C         H          MESH WIDTH OF INDEPENDENT VARIABLES  (EQ-SPASES)
                   C         F(I)       DIMENSION OF GIVEN FUNCTION  I=1,2,...,M
                   C         S          INTEGRATED VALUE OF FUNCTION
                   C         IER        ERROR CODE     =0   NORMAL
                   C                                   =1   ABNORMAL, S IS SET FOR S = 0.0
                   C
                   C
  ISN 00002              DIMENSION F(M)
                   C
  ISN 00003              MM = (M-1)/2*2
  ISN 00004              IF (MM.EQ.M-1) GO TO 10
  ISN 00005              IER = 1
  ISN 00006              S = 0.0
  ISN 00007              PRINT 100, IER,M
  ISN 00008              RETURN
                   C
  ISN 00009           10 N = (M-1)/2
  ISN 00010              S2 = 0.0
  ISN 00011              S4 = 0.0
                   C
  ISN 00012              DO 20 I=1,N
  ISN 00013              IF (I.EQ.N) GO TO 15
  ISN 00014              K2 = 2*I+1
  ISN 00015              S2 = S2+F(K2)
  ISN 00016           15 K4 = 2*I
  ISN 00017           20 S4 = S4+F(K4)
                   C
  ISN 00018              S = H*(F(1)+F(M)+4.0*S4+2.0*S2)/3.0
  ISN 00019              IER = 0
  ISN 00020              RETURN
  ISN 00021          100 FORMAT (/// T10, 10('*'), ' ERROR IN SUBROUTINE-SIMPSN ',10('*'),
                        1          / T10, 'M MUST BE ODD NUMBER  IER =',I2, '  M =',  I4 )
                   C
  ISN 00022              END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.26  TIME 14.49.07

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

 ISN 00001           SUBROUTINE HERMAN
               C
               C          THIS ROUTINE CALCULATES AVERAGE AND LOCAL NUSSELT NUMBERS
               C          AROUND HORIZONTAL CYLINDER WITH HERMANN-SPARROW,S THEORY FOR
               C          ISO-THERMAL CONDITION.
               C     RAO              RAYLEIGH NUMBER AROUND OUTER WALL
               C     AVNU             AVERAGE NUSSELT NUMBER
               C     WNU(J)           LOCAL NUSSELT NUMBER
               C
 ISN 00002           COMMON/WALLC/ WNU(41),AVNU,TCWBYI,TCWBYO,RAO
 ISN 00003           COMMON/INTEC/ M,N,MCAL,NCAL,MW,KW,KALP,KDIST
 ISN 00004           COMMON/INDEP/ RI(41),PHI(41),DR,DRT,DRI,DRW,DPH
               C
 ISN 00005           DIMENSION  COH(10)
               C
 ISN 00006           DATA ( COH(I),I=1,10 )/ 1.239,0.13682,-1.0866, 2.3380, -1.9872,
                    1       0.10608, 0.88092, -0.57811, 0.15075, -0.01454 /
               C
 ISN 00007           AVNU = 0.399*RAO**0.25
               C
 ISN 00008           DO 20 J=1,N+1
 ISN 00009           IF (PHI(J).EQ.0.0) GO TO 2
 ISN 00010           WNU(J) = 0.0
 ISN 00011           GO TO 5
 ISN 00012         2 WNU(J) = COH(1)
 ISN 00013           GO TO 20
 ISN 00014         5 DO 10 I=1,10
 ISN 00015        10 WNU(J) = WNU(J)+COH(I)*PHI(J)**(I-1)
 ISN 00016        20 WNU(J) = AVNU*WNU(J)
 ISN 00017           PRINT 100, RAO,AVNU,WNU(1),WNU(N+1)
 ISN 00018       100 FORMAT ( //// T18, 37('*'), ' SUBROUTINE  HERMAN ',  37('*')  ///
                    1     T29, 'RAYLEIGH NO', T50, 'AVERAGE NU',  T72, 'MAX NU', T92,
                    2     'MIN NU', / T32, '(RAO)', T51, '(AVNU)', T70, '(WNU(1) )',
                    3     T90, '(WNU(N+1) )'  // T20, 1P4E20.4 // T18, 94('*') // )
 ISN 00019           RETURN
 ISN 00020           END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.26  TIME 14.49.08

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001           SUBROUTINE VISUAL ( X,Y,Z,M,N,XA,YA,ZA,ZYJ,ZIIJ,ZII,KZ)
                C
                C     THIS ROUTINE VISUALIZE 3-DIMENSIONAL ARRAYS BY EASY METHOD.
                C
                C        X(I)   X-COORDINATE OF Z(I,J)  I=1,2, ... ,M
                C        Y(J)   Y-COORDINATE OF Z(I,J)  J=1,2, ... ,N
                C        Z(I,J) FUNCTION OF X(I),Y(J)  (VISUALIZING VALUES)
                C
                C     **REMARKS**
                C       (1) X AND Y MUST BE MONOTONIC CHANGE AND EQ.-SPACES
                C       (2) VISUALIZING PLANE IS 50 X 50  CHARACTERS
                C       (3) X AND Y DIRECTION ARE HORIZONTAL AND VERTICAL RESPECTI-
                C           VLY
                C       (4) THIS ROUTINE NEEDS SUBROUTINE 'D2ITPL' AND 'INTPL2'
                C
  ISN 00002           DIMENSION X(M),Y(N),Z(M,N),XA(50),YA(50),ZA(50,50),ZYJ(M),ZII(N),
                     1          ZIIJ(50,N),KZ(50,50)
                C
  ISN 00003           DATA KBLANK,KA   / ' ','A'  /
                C
  ISN 00004           CALL D2ITPL  (X,Y,Z,M,N,XA,YA,ZA,50,50,IERR,ZYJ,ZIIJ,ZII)
  ISN 00005           IF (IERR.EQ.0) GO TO 10
  ISN 00006           PRINT 1000
  ISN 00007           STOP
                C
  ISN 00008        10 XAMAX = XA(1)
  ISN 00009           XAMIN = XA(1)
  ISN 00010           YAMAX = YA(1)
  ISN 00011           YAMIN = YA(1)
  ISN 00012           ZAMAX = ZA(1,1)
  ISN 00013           ZAMIN = ZA(1,1)
                C
                C
  ISN 00014           DO 20 I=2,50
  ISN 00015           IF (XA(I).GT.XAMAX) XAMAX = XA(I)
  ISN 00016           IF (XA(I).LT.XAMIN) XAMIN = XA(I)
  ISN 00017        20 CONTINUE
                C
  ISN 00018           DO 30 J=2,50
  ISN 00019           IF (YA(J).GT.YAMAX) YAMAX = YA(J)
  ISN 00020           IF (YA(J).LT.YAMIN) YAMIN = YA(J)
  ISN 00021        30 CONTINUE
                C
  ISN 00022           DO 40 J=1,50
  ISN 00023           DO 40 I=1,50
  ISN 00024           IF (ZA(I,J).GT.ZAMAX) ZAMAX = ZA(I,J)
  ISN 00025           IF (ZA(I,J).LT.ZAMIN) ZAMIN = ZA(I,J)
  ISN 00026        40 CONTINUE
                C
                C
                C                         NORMALIZATION OF Z(I,J)
  ISN 00027           DO 50 J=1,50
  ISN 00028           DO 50 I=1,50
                C     ZA(I,J) = (ZA(I,J)-ZAMIN)/(ZAMAX-ZAMIN)*1.1
                C     IF (ZA(I,J).GE.1.1) ZA(I,J) = 1.0
  ISN 00029           ZA(I,J) = ZA(I,J)*10.0
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18     VISUAL  DATE 83.01.26  TIME 14.49.08

  ISN 00030            KZ(I,J) = ZA(I,J) + 1
  ISN 00031            KZ(I,J) = KZ(I,J)*1000
  ISN 00032            KZA = KZ(I,J)/2000*2000
  ISN 00033            IF (KZA.EQ.KZ(I,J)) GO TO 45
  ISN 00034            IF (KZ(I,J).EQ.11000) GO TO 41
  ISN 00035.           KZ(I,J) = IBTOD(KZ(I,J))
  ISN 00036            GO TO 50
  ISN 00037         41 KZ(I,J) = KA
  ISN 00038            GO TO 50
  ISN 00039         45 KZ(I,J) = KBLANK
  ISN 00040         50 CONTINUE
                 C
  ISN 00041            PRINT 1010, XAMAX,XAMIN
  ISN 00042            PRINT 1020, YAMAX,YAMIN
  ISN 00043            PRINT 1030, ZAMAX,ZAMIN
                 C
  ISN 00044            DO 60 J=1,50
  ISN 00045         60 PRINT 1040, (KZ(I,J), I=1,50)
                 C
                 C
  ISN 00046            RETURN
                 C
                 C
  ISN 00047       1000 FORMAT ( '1    ERROR HAPPENED IN SUBROUTINE VISUAL '  )
                 C
  ISN 00048       1010 FORMAT( '1' //  T10, 'XMAX =',1PE13.4 / T10, 'XMIN =',1PE13.4  )
                 C
  ISN 00049       1020 FORMAT (      T10,'YMAX =',1PE13.4 / T10, 'YMIN =',1PE13.4   )
  ISN 00050       1030 FORMAT (      T10,'ZMAX =',1PE13.4 / T10, 'ZMIN =',1PE13.4 / )
                 C
  ISN 00051       1040 FORMAT (  T40,  50A1   )
                 C
  ISN 00052            END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.26  TIME 14.49.08

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

   ISN 00001            SUBROUTINE INTPL2( A, B, X, Y, N, IERR )
                  C
                  C     THIS ROUTINE INTERPOLATES THE Y-VALUE TO THE X-VALUE  BY SECOND
                  C     ORDER INTERPOLATION.
                  C
                  C         A(N)        TABLE OF X(I),(I=1,2, , , ,N)
                  C         B(N)        TABLE OF Y(I),(I=1,2, , , ,N)   B(I)=FUNC(A(I))
                  C         X           GIVEN X
                  C         Y           Y-VALUE FOR X  (CALCULATED VALUE)
                  C         N           NUMBER(SIZE) OF POINTS IN TABLE
                  C         IERR        ERROR CODE
                  C
                  C             IERR=0   NORMAL CONDITION
                  C                 =2   VALUE OF X IS OUT-SIDE OF A(N) (MUST BE INSIDE)
                  C                 =3   A IS NOT UNIQUE
                  C
   ISN 00002            DIMENSION A(N),B(N)
                  C
   ISN 00003            DO 10 K=1,N
   ISN 00004            IF ( A(K).NE.X )  GO TO 10
   ISN 00005            Y=B(K)
   ISN 00006            IERR=0
   ISN 00007            RETURN
   ISN 00008         10 CONTINUE
                  C
   ISN 00009            IF ( N .GE. 3) GO TO 11
   ISN 00010            IERR = 1
   ISN 00011            RETURN
                  C
   ISN 00012         11 IERR = 0
   ISN 00013            OX = A(1)
   ISN 00014            IF ( A(N)-OX ) 31,12,21
   ISN 00015         12 IERR = 3
   ISN 00016            RETURN
                  C
   ISN 00017         21 IF ( X. LT. OX ) GO TO 19
                  C
   ISN 00018            DO 23 K=2,N
   ISN 00019            IF ( A(K) .LE. OX ) GO TO 12
   ISN 00020            OX = A(K)
   ISN 00021            IF ( X .LE. OX ) GO TO 100
   ISN 00022         23 CONTINUE
                  C
   ISN 00023         19 IERR = 2
   ISN 00024            RETURN
                  C
   ISN 00025         31 IF ( X .GT. OX ) GO TO 19
   ISN 00026            DO 33 K=2,N
   ISN 00027            IF ( A(K) .GE. OX ) GO TO 12
   ISN 00028            OX = A(K)
   ISN 00029            IF ( X .GE. OX ) GO TO 100
   ISN 00030         33 CONTINUE
   ISN 00031            GO TO 19
                  C
   ISN 00032        100 DX = OX - A(K-1)
   ISN 00033            IF (K .GT. 2 ) K=K-1
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      INTPL2  DATE 83.01.26  TIME 14.49.08

   ISN 00034        P = ( X-A(K) ) / DX                                                  00043020
   ISN 00035        Y = P*(1.+P)/2.*B(K+1) + (1.+P)*(1.-P)*B(K) - P*(1.-P)/2.*B(K-1)     00043030
   ISN 00036        RETURN                                                               00043040
   ISN 00037        END                                                                  00043050
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.26  TIME 14.49.08

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

   ISN 00001            SUBROUTINE  D2ITPL( X,Y,Z,M,N,XX,YY,ZZ,MM,NN,IERR,ZYJ,ZIIJ,ZII )
                  C
                  C       THIS ROUTINE TRANSFORMES 2-DIMENSIONAL ARRAY Z( X(I),Y(J) )
                  C     TO  ZZ( XX(II),YY(JJ) ) IN THE SAME PLANE BY 2ND-ORDER INTERPOLA-
                  C     TION.
                  C      WHERE, I=1,2,,,  ,M      (M.GE.3)
                  C             J=1,2,,,  ,N      (N.GE.3)
                  C            II=1,2,,,  ,MM
                  C            JJ=1,2,,,  ,NN
                  C       X(I),Y(J),XX(II) AND YY(JJ) MUST BE PLACED IN SAME SPACES.
                  C     ** THIS ROUTINE NEEDS SUBROUTINE INTPL2
                  C       Z( X(I),Y(J) )         OLD 2-D ARRAY  (INPUT ARRAY)
                  C       ZZ(XX(II),YY(JJ)       NEW 2-D ARRAY  (OUTPUT ARRAY)
                  C       IERR                   ERROR CODE   IERR=0  NORMAL CONDITION
                  C                                           IERR=1  ABNORMAL CONDITION
                  C       ZYJ(I)        AUX ARRAY
                  C       ZIIJ(II,J)
                  C       ZII(J)
   ISN 00002            DIMENSION X(M),Y(N),Z(M,N),XX(MM),YY(NN),ZZ(MM,NN),ZYJ(M),
                       1          ZIIJ(MM,N),ZII(N)
                  C         MESH POINTS TRANSFORMATION
   ISN 00003            XL=X(M)-X(1)
   ISN 00004            YL=Y(N)-Y(1)
   ISN 00005            DO 10 II=1,MM
   ISN 00006         10 XX(II)=X(1)+XL*(II-1)/(MM-1)
   ISN 00007            DO 20 JJ=1,NN
   ISN 00008         20 YY(JJ)=Y(1)+YL*(JJ-1)/(NN-1)
                  C
                  C         X-COORDINATE PITCH TRANSFORMATION (INTERPOLATION)
   ISN 00009            DO 30 J=1,N
   ISN 00010            DO 25 I=1,M
   ISN 00011         25 ZYJ(I)=Z(I,J)
   ISN 00012            DO 30   II=1,MM
   ISN 00013            CALL INTPL2( X, ZYJ, XX(II), ZIIJ(II,J), M, IER1 )
   ISN 00014            IF (IER1.EQ.0)    GO TO 30
   ISN 00015            PRINT 100
   ISN 00016            IERR=1
   ISN 00017            RETURN
   ISN 00018         30 CONTINUE
                  C         Y-COORDINATE PITCH TRANSFORMATION
   ISN 00019            DO 40 II=1,MM
   ISN 00020            DO 35 J=1,N
   ISN 00021         35 ZII(J)=ZIIJ(II,J)
   ISN 00022            DO 40 JJ=1,NN
   ISN 00023            CALL INTPL2( Y, ZII, YY(JJ), ZZ(II,JJ), N, IER2 )
   ISN 00024            IF (IER2.EQ.0)    GO TO 40
   ISN 00025            PRINT 200,IER2,II,JJ
   ISN 00026            IERR=1
   ISN 00027            RETURN
   ISN 00028         40 CONTINUE
   ISN 00029            IERR=0
   ISN 00030        100 FORMAT ( ///  T20,'ERROR HAPPEND IN SUBROUTINE D2ITPL (X-PITCH INT
                       1ERPOLATION)',/T20,'ERROR CODE =',I5, T40,'REFER ITPL2' /
                       2               T20,'      J      =',I5, /
                       3               T20,'      II     =',I5   // )
                  C
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      D2ITPL  DATE 83.01.26  TIME 14.49.08

  ISN 00031        200 FORMAT ( ///  T20,'ERROR HAPPEND IN SUBROUTINE D2ITPL (Y-PITCH INT00043620
                      1ERPOLATION)',/T20,'ERROR CODE =',I5, T40,'REFER ITPL2' /            00043630
                      2                 T20,      'II     =',I5, /                         00043640
                      3                 T20,      'JJ     =',I5    // )                    00043650
                 C                                                                         00043660
  ISN 00032              RETURN                                                            00043670
  ISN 00033              END                                                               00043680
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.26  TIME 14.49.09

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001              SUBROUTINE  OPTOM
                   C
                   C            THIS ROUTINE OPTIMIZES RELAXATION FACTOR(OMEGA) FOR S.O.R.
                   C            AUTOMATICALLY.
                   C            UPPER AND LOWER LIMIT OF OMEGA IS LIMITTED BY DATA STATEMENT.
                   C
                   C        IOMEGA          COUNT FOR OMEGA ADJUSTING CYCLE
                   C        TRACER          CODE FOR OMEGA ADJUSTING; '+': INCREASING
                   C                                                  '-': DECREASING
                   C                                                  'O': NO ADJUSTING
                   C        OMEGA           RELAXATION FACTOR
                   C        DOM             OMEGA ADJUSTING WIDTH
                   C        NSIGN           SIGN FROM S.O.R. ROUTINE; 1: NORMAL
                   C                                                 -1: OMEGA TOO LARGE
                   C        TN(I,J)         GRID DATA IN S.O.R. ROUTINE
                   C        TOLD(I,J)       RESERVED TN(I,J)
                   C            WHERE  I=1,2,... M+1  J=1,2,... N+1
                   C
                   C                        SPECIAL COMMON FOR THIS ROUTINE
  ISN 00002              COMMON/COMOPT/ IOMEGA,DOM,NSIGN,TOLD(41,41),TRACER,DOMMIN
                   C                        GENERAL COMMON TO LINK TN(I,J) AND OMEGA ETC,.
  ISN 00003              COMMON/TPUVC/ TN(41,41),PSI(41,41),U(41,41),V(41,41)
  ISN 00004              COMMON/INTEC/ M,N,MCAL,NCAL,MW,KW,KALP,KDIST
  ISN 00005              COMMON/SORCO/ OMEGA,OMPSI,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,
                       1                ERRORP
                   C
  ISN 00006              DOUBLE PRECISION TN,PSI
  ISN 00007              DOUBLE PRECISION TOLD
  ISN 00008              DATA OMMAX,OMMIN /1.860,1.00 /
  ISN 00009              DATA UP,ZERO,DOWN/ '+','O','-'/
                   C
  ISN 00010              IF (IOMEGA.EQ.O.OR.IOMEGA.EQ.1) GO TO 5
  ISN 00011              IF (TRACER.EQ.UP.OR.TRACER.EQ.DOWN) GO TO 5
  ISN 00012              GO TO 6
                   C
  ISN 00013            5 IOMEGA = IOMEGA + 1
  ISN 00014            6 IF (IOMEGA.EQ.1) GO TO 10
                   C
  ISN 00015              IF (NSIGN.EQ.1) GO TO 20
  ISN 00016              IF (NSIGN.EQ.-1) GO TO 100
                   C
                   C                        NSIGN IS NOT DEFINED
  ISN 00017              PRINT 1000
  ISN 00018              WRITE(6,500)
  ISN 00019          500 FORMAT('      NSIGN  NOT  DEFINED      ')
  ISN 00020              STOP
                   C
  ISN 00021           10 OMEGA = OMMAX
  ISN 00022              DOM = 0.1*(OMMAX-OMMIN)
                   C
                   C                        RESERVATION OF TN(I,J)
  ISN 00023           20 DO 30 J=1,N+1
  ISN 00024              DO 30 I=1,M+1
  ISN 00025           30 TOLD(I,J) = TN(I,J)
                   C
  ISN 00026              IF (IOMEGA.EQ.1) GO TO 40
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18       OPTOM  DATE 83.01.26  TIME 14.49.09

   ISN 00027            GO TO 45
                  C                      INITIAL OMEGA CYCLE
   ISN 00028         40 TRACER = ZERO
   ISN 00029            RETURN
                  C
   ISN 00030 ·       45 IF (DOM.GT.DOMMIN) GO TO 50
                  C
                  C                      SATURATED OMEGA
   ISN 00031            TRACER = ZERO
   ISN 00032            RETURN
                  C
   ISN 00033         50 IF (TRACER.EQ.DOWN.AND.ITERA.GT.1) DOM = 0.1*DOM
   ISN 00034            TRACER = UP
                  C
                  C                      OMEGA INCREASING
   ISN 00035            OMEGA = OMEGA + DOM
                  C
   ISN 00036            PRINT 1200, IOMEGA,OMEGA,DOM,NSIGN,TRACER
   ISN 00037            RETURN
                  C
                  C                      OMEGA DECREASING LOOP
   ISN 00038        100 TRACER = DOWN
                  C
                  C                      TN(I,J) RESET
   ISN 00039            DO 110 J=1,N+1
   ISN 00040            DO 110 I=1,M+1
   ISN 00041        110 TN(I,J) = TOLD(I,J)
                  C
                  C                      OMEGA DECREASING
   ISN 00042            OMEGA = OMEGA - DOM
                  C
   ISN 00043            PRINT 1200, IOMEGA,OMEGA,DOM,NSIGN,TRACER
   ISN 00044            RETURN
                  C
                  C                      ALARM MESSAGE FORMATS
   ISN 00045       1000 FORMAT ( // T10,'NSIGN SHOULD BE DEFINED IN S.O.R. ROUTINE',
                      1            / T10, 'NSIGN SHOULD BE INCLUDE IN COMMON STATEMENT'/)
                  C
                  C                      MESSAGE FORMAT
   ISN 00046       1200 FORMAT(T2,10('*'),2X,'IOMEGA =',I4, 5X, 'OMEGA =', F7.4, 5X,
                      1          'DOM =', 1PE13.3, 5X, 'NSIGN = ', I2, 5X, 'TRACER =',A1,
                      2          5X, 10('*')  )
                  C
```

FACOM OSIV/F4 FORTRAN IV (HE) V04L18 DATE 83.01.26 TIME 14.49.10

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

```
               C
               C
               C
ISN 00001            SUBROUTINE  PTSNGL
               C
               C
               C
ISN 00002            COMMON/INTEC/M,N,MCAL,NCAL,MW,KW,KALP,KDIST
ISN 00003            COMMON/TPUVC/TN(41,41),PSI(41,41),U(41,41),V(41,41)
ISN 00004            COMMON/SCOMM/TNS(41,41),PSIS(41,41)
ISN 00005            DOUBLE  PRECISION   TN,PSI
ISN 00006            DO   10   IR  =  1,MCAL
ISN 00007            DO  10  JP  =  1,NCAL
ISN 00008            TNS(IR,JP)=TN(IR,JP)
ISN 00009         10 PSIS(IR,JP)  =  PSI(IR,JP)
ISN 00010            RETURN
ISN 00011            END
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.26  TIME 14.49.10

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

                C
  ISN 00001           SUBROUTINE   PLDATA(R,PHI,Z,M,N,RMAX)
                C
                C     THIS  ROUTINE  CHANGES  POLAR  COODINATE  TO  RECTANGULAR
                C     COODINATE  AND  WRITES  X,Y,ZNORM  DATA  IN  DISK  FILE  FOR  GPCP
                C
                C
                C
                C     R(I)      (I=1,2,....M)   RADIUS  OF  POLAR  COODINATE
                C     PHI(J)    (J=1,2,....N)   ANGLES  OF  POLAR  COODINATE
                C     Z(I,J)                    HEIGHT  OF  POINT  R(I),PHI(J)
                C     ZNORM                     NORMALIZED  Z(I,J)
                C     X
                C     X                         X  COODINATE  OF  R(I),PHI(J)
                C     Y                         Y  COODINATE  OF  R(I),PHI(J)
                C
                C
                C
                C
  ISN 00002           DIMENSION  R(M),PHI(N),Z(M,N)
                C
  ISN 00003           ZMIN=Z(1,1)
  ISN 00004           ZMAX=Z(1,1)
                C
  ISN 00005           DO  10   J  =  1,N
  ISN 00006           DO  10   I  =  1,M
  ISN 00007           IF(Z(I,J).GT.ZMAX)     ZMAX=Z(2,J)
  ISN 00008           IF(Z(I,J).GT.ZMAX)     ZMAX=Z(I,J)
  ISN 00009        10 IF(Z(I,J).LT.ZMIN)     ZMIN  =  Z(I,J)
                C
  ISN 00010           DO  20   J  =  1,N
  ISN 00011           DO   20   I  =  1,M
                C
                C
  ISN 00012           ZNORM  =  (Z(I,J)-ZMIN)/(ZMAX-ZMIN)
  ISN 00013           X  =  R(I)*SIN(PHI(J))/RMAX
  ISN 00014           Y  =  -R(I)*COS(PHI(J))/RMAX
                C
                C
  ISN 00015           WRITE(3,1040)   X,Y,ZNORM
  ISN 00016        20 CONTINUE
  ISN 00017           WRITE(3,1045)
  ISN 00018           PRINT  1050
  ISN 00019      1040 FORMAT('CNTL',T6,3F10.5,T72,'2')
  ISN 00020      1045 FORMAT('BEND')
  ISN 00021      1050 FORMAT('1',///,
                     *    T10,'  X,Y  AND  ZNORM  ARE  WRITE  IN  DISK  FILE'/////)
  ISN 00022           RETURN
  ISN 00023           END
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.26  TIME 14.49.10

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

                C
                C
                C
   ISN 00001          SUBROUTINE  TABLE(Z,XLETER)
                C
                C
   ISN 00002          COMMON/INTEC/M,N,MCAL,NCAL,MW,KW,KALP,KDIST
   ISN 00003          COMMON/PARAC/RO,RW,PHIMAX,RADA
   ISN 00004          COMMON/SORCO/OMEGA,OMPSI,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,
                     1          ERRORP
   ISN 00005          COMMON/WALLC/WNU(41),AVNU,TCWBYI,TCWBYO,RAO
                C
                C
                C
                C
   ISN 00006          DIMENSION  Z(MCAL,NCAL),XLETER(2)
                C
                C
   ISN 00007          DO  70   L=1,M,11
   ISN 00008          IF(L+10.GT.M+1)      GO  TO   20
   ISN 00009          LL   =  L+10
   ISN 00010          GO  TO   30
   ISN 00011       20 LL   =   M+1
                C
                C
   ISN 00012       30 JLINE   =  0
   ISN 00013          DO 70    J= 1,N+1
   ISN 00014          IF(JLINE.GT.0)       GO  TO   60
                C
   ISN 00015          PRINT 100,RADA,RO,M,N,OMEGA,ITERA,ERROR
   ISN 00016          IF(KALP.EQ.1)      GO  TO   40
   ISN 00017          GO  TO   50
   ISN 00018       40 PRINT 110,AVNU,RW,MW,KW,TCWBYI,TCWBYO
   ISN 00019          IF(KDIST.EQ.1)       GO  TO   42
   ISN 00020          GO  TO   44
   ISN 00021       42 PRINT 150
   ISN 00022          GO  TO   50
   ISN 00023       44 PRINT 160
   ISN 00024       50 PRINT 120,(XLETER(I),I=1,2)
   ISN 00025          PRINT 130,((I),I=L,LL)
                C
                C
   ISN 00026       60 PRINT 140,J,(Z(I,J),I=L,LL)
   ISN 00027          JLINE=JLINE+1
   ISN 00028          IF(JLINE.EQ.24)       JLINE=0
   ISN 00029       70 CONTINUE
                C
                C
                C
   ISN 00030          RETURN
                C
                C
                C
                C
                C
                C
```

```
FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        TABLE  DATE 83.01.26  TIME 14.49.10

  ISN 00031        100 FORMAT('1'////T7,'RADA =',1PE9.2,T27,' RO  =',0PF6.2,T43,
                      1         'M  =',I3,T55,' N  =',I3,T67,'OMEGA =',1PE11.4,T91,
                      2         'ITERA =',I4,T113,'ERROR =',1PE10.3)
                 C
  ISN 00032        110 FORMAT(/T7,'AVNU =',1PE9.2,T27,' RW  =',0PF6.2,T43,
                      1         'MW  =',I3,T55,' KW  =',I3,T67,'TCWBYI=',1PE11.4,
                      2         T91,'TCWBYO=',1PE11.4)
                 C
                 C
  ISN 00033        120 FORMAT(//T50,'DIMENSION LESS  ',A4,A2,' DISTRIBUTION '/T50,
                      1         34('-'))
                 C
                 C
  ISN 00034        130 FORMAT(/T13,10('I  =',I3,5X))
  ISN 00035        140 FORMAT(/T3,'J  =',I3,T10,1P11E11.3)
  ISN 00036        150 FORMAT('+',T113,'WNU(J)=VARIABLE')
  ISN 00037        160 FORMAT('+',T113,'WNU(J)=CONSTANT')
                 C
                 C
                 C
                 C
                 C
  ISN 00038            END
```

(2)FACOM OSIV/F4 FORTRAN IV (HE) V04L18   DATE 83.01.17 TIME 14.02.20

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

```
C          NAPHAS3           NOV. 1976              BY H.SHIMOMURA
C       THIS PROGRAM COMPUTES THERMAL AND FLUID-DYNAMIC PERFORMANCES IN
C       HORIZONTAL ANNULAR POROUS SPACES IN GRAVITATIONAL FIELD.
C
C       REFERECE DOCUMENTATION   JAERI-M-
C
C       VARIABLES DEFINITION
C
C       TN(I,J)        D-LESS TEMPERATURE AT ITERATION CYCLE ITERA
C       RI(I)          D-LESS RADIAL ARGUMENT (INNER RADIUS  =1)
C       PHI(J)         ANGULAR ARGUMENT
C       RMIN           MINIMUM D-LESS RADIUS FOR CALCULATION (RMIN=1)
C       RMAX           MAXIMUM D-LESS RADIUS FOR CALC.(=OUTER R./INNER R.)
C       PHMIN          MINIMUM ANG.ARG. FROM BOTTOM CENTER (=0.0)
C       PHMAX          MAXIMUM ANG.ARG. FROM BOTTOM CENTER (=3.14... )
C       M              NUMBER OF RADIAL MESH FOR CALCULATION
C       N              NUMBER OF CIRCUMFERENTIAL MESH FOR CALC.
C       DR             RADIAL MESH WIDTH FOR CALC.
C       DPH            ANGULAR MESH WIDTH FOR CALC.
C       EXOMEG         RELAXATION FACTOR GIVEN EXTERNALLY FOR ENERGY EQ.
C       ITERA          NUMBER OF ITERATION CYCLE
C       ITEL           LIMITED NUMBER OF ITERATION
C       SOLD           SUMMATION OF TO(I,J)
C       SNEW           SUMMATION OF TN(I,J)
C       OMEGA          RELAXATION FACTOR FOR ENERGY EQ.
C       OMPSI          RELAXATION FACTOR FOR EQ. OF MOTION
C       ERROR          ALLOWABLE CALCULATION ERROR FOR TN(I,J) AND PSI(I,J)
C       PSI(I,J)       D-LESS STREAM FUNCTION AT ITERATION CYCLE ITERA
C       DTDRO(J)       D-LESS RADIAL TEMP. GRADIENT AT R=RO/RI
C       DTDRI(J)       D-LESS RADIAL TEMP. GRADIENT AT R=1.0
C       U(I,J)         D-LESS RADIAL VELOCITY
C       V(I,J)         D-LESS ANGULAR VELOCITY
C       AVNUSO         AVERAGE NUSSELT NUMBER AT R=RO/RI
C       AVNUSS         AVERAGE NUSSELT NUMBER AT R=1.0
C       QIBYGM(J)      RELATIVE LOCAL HEAT FLUX AT INNER WALL(HEAT T COEFF)
C                      = ((KE/K)LOCAL)/((KE/K)AV.) AT R=1.0
C       QOBYGM(J)      RELATIVE LOCAL HEAT FLUX AT OUTER WALL(HEAT.T COEFF)
C                      = ((KE/K)LOCAL)/((KE/K)AV.) AT R=RO/RI
C       EKBYK(J)       RATIO OF EFFECTIVE AND MOLEC. T.CONDUCT. AT R=1.0
C       EKBYKO(J)      RATIO OF EFFECTIVE AND MOLEC. T.CONDUCT. AT R=RO/RI
C       CONT(I)        OPTION CONTROLLER (I=1,2, ..,20)
C       CONT(1) = 'A';EXTERNAL OMEGA IS USED, IF CONT(1).NE.'A',AUTOMATIC.
C       CONT(2) = 'A';INTERPOLATED TEMPERATUR TABLES ARE PRINTED
C       CONT(3) = 'A';INTERPOLATED STREAM FUNCTION TABLES ARE PRINTED
C       CONT(4) = 'A';GRAPHIC TEMPERATUR DISTRIBUTION IS PRINTED
C       CONT(5) = 'A';GRAPHIC FLOW PATTERN IS PRINTED
C       CONT(6) = 'A';DATA FOR ISO-THERMAL LINE PLOTTING ARE OUTPUT IN
C                      DISK FILE. (CONTROL CARDS ARE NECESSARY)
C       CONT(7) = 'A';DATA FOR STREAM LINE PLOTTING ARE OUTPUT IN
C                      DISK FILE. (CONTROL CARDS ARE NECESSARY)
C       CONT(8) = 'A':GRAPHIC VORTICITY PATTERN IS PRINTED
C       CONT(9) = 'A';GRAPHIC INERTIA PATTERN IS PRINTED
C       OPT            GRAPHIC OPTION CONTROLLER, IF OPT='SIMA', STRIPED
C                      GRAPHIC-PATTERNS ARE PRINTED
C       RADA           RAYLEIGH NUMBER * DARCY NUMBER
C
```

FACOM OSIV/F4 FORTRAN IV (HE) V04L18   DATE 83.01.17 TIME 14.02.20

```
                 C
ISN 00001              COMMON/VELCO/ U( 41, 41),V( 41, 41)
ISN 00002              COMMON/INDEP/ RI( 41),PHI( 41),DR,DPH
ISN 00003              COMMON/TNPSI/ TN( 41, 41),PSI( 41, 41),RADA
ISN 00004              COMMON/SIGMA/ SNEW,SOLD,SPSI,SPSIO
ISN 00005              COMMON/RPHIC/ RMIN,RMAX,PHMIN,PHMAX
ISN 00006              COMMON/INTEC/ M,N,MCAL,NCAL
ISN 00007              COMMON/SORCO/ OMEGA,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,OMPSI
ISN 00008              COMMON/CONCO/ CONT(80)
ISN 00009              COMMON/INERC/ SAHEN(41,41),UHEN(41,41),SBYU(41,41)
ISN 00010              DOUBLE PRECISION TN,OMEGA,DR,RI,DPH,RADA,PHI,PSI,OMPSI
ISN 00011              DOUBLE PRECISION U,V
ISN 00012              DIMENSION TNS(41,41), RIS(41), PHIS(41), XX( 50), YY( 50),
                     1          ZZ( 50, 50), ZYJ(41), ZIIJ( 50,41), ZII(41),
                     2          PSIS(41,41), XXP( 50), YYP( 50), ZZP( 50, 50), ZYJP(41),
                     3          ZIIJP( 50,41), ZIIP(41),EKBYK( 41),DTDRO( 41),
                     4          EKBYKO( 41),DTDRI( 41)
ISN 00013              DIMENSION ZETA( 41, 41)
ISN 00014              DIMENSION KZ(50,50),NZ(50,50)
ISN 00015              DIMENSION QIBYQM( 41),QOBYQM( 41)
                 C
ISN 00016              DATA  CP, CN / 'A',' '/
ISN 00017              DATA ALPHBC/'ALPH'/
ISN 00018              RMIN = 1.
ISN 00019              PHMIN = 0.
ISN 00020              PHMAX = 3.1415926
ISN 00021              CALL DATAON
                 C
ISN 00022              READ (5,1) M,N,ITEL,MPRINT,NPRINT
ISN 00023              MCAL = M+1
ISN 00024              NCAL = N+1
ISN 00025              READ (5,2) RMAX,RADA,ERROR,EXOMEG,OMPSI
ISN 00026              READ (5,3) (CONT(K),K=1,20),OPT,BCOUT
                 C
ISN 00027              IF(CONT(1).NE.CP) GO TO 4
ISN 00028              OMEGA=EXOMEG
ISN 00029              GO TO 5
                 C          CALCULATION OF OPTIMUM OMEGA
ISN 00030            4 A=3.1415926/M
ISN 00031              B=3.1415926/N
ISN 00032              TXY=COS(A)+COS(B)
ISN 00033              OMEGA=4.0-TXY**2.0
ISN 00034              OMEGA=DSQRT(OMEGA)
ISN 00035              OMEGA=(8.0-4.0*OMEGA)/TXY**2.0
                 C
                 C          MESH SIZE
ISN 00036            5 DR=(RMAX-RMIN)/M
ISN 00037              DPH=(PHMAX-PHMIN)/N
                 C
ISN 00038              DO 10 I=1,M+1
ISN 00039           10 RI(I)=1.0+(I-1)*DR
                 C
ISN 00040              DO 20 J=1,N+1
ISN 00041           20 PHI(J)=PHMIN+(J-1)*DPH
                 C
ISN 00042              ITERA=0
                 C
ISN 00043              DO 30 J=1,N+1
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        MAIN  DATE 83.01.17  TIME 14.02.20
  ISN 00044              DO 30 I=1,M+1
  ISN 00045              TN(I,J)=(RMAX-RI(I))/(RMAX-RMIN)
                   C
                   C
  ISN 00046           30 PSI(I,J) = 0.0
                   C
  ISN 00047           40 CONTINUE
                   C
  ISN 00048              SOLD=0.0
  ISN 00049              SNEW=0.0
                   C
  ISN 00050              CALL SIMSOL
                   C
                   C
                   C
  ISN 00051              EPS=(SNEW-SOLD)/SNEW
  ISN 00052              APS = ABS(EPS)
  ISN 00053              IF(APS.LE.ERROR) GO TO 75
  ISN 00054              IF(ITERA.LE.ITEL) GO TO 70
                   C     LATEST DATA OUTPUT
  ISN 00055              PRINT 65, ITERA,OMEGA,EPS
  ISN 00056              GO TO 80
                   C
  ISN 00057           70 ITERA = ITERA+1
  ISN 00058              PRINT 240, ITERA,ITEP,APS,ERRPSI,OMEGA,OMPSI
                   C
  ISN 00059              GO TO 40
                   C
  ISN 00060           75 CONTINUE
  ISN 00061              PRINT 230, ITERA,ITEP,EPS,ERRPSI
  ISN 00062           80 CALL VELOCI
  ISN 00063              CALL PTSNGL (TN,PSI,RI,PHI,TNS,PSIS,RIS,PHIS,MCAL,NCAL)
                   C
  ISN 00064              CALL VORTIC (RADA,TNS,DR,RI,PHI,DPH,MCAL,NCAL,ZETA)
  ISN 00065              DO 76 L=1,M,11
  ISN 00066              IF (L+10.GT.M+1) GO TO 81
  ISN 00067              LL = L+10
  ISN 00068              GO TO 82
  ISN 00069           81 LL = M+1
  ISN 00070           82 CONTINUE
  ISN 00071              PRINT 101, RADA,RMAX,M,N,OMEGA,ERROR,ITERA,ITEP,OMPSI
  ISN 00072              PRINT 100, (I, I=L,LL)
  ISN 00073              DO 76 J=1,N+1
  ISN 00074           76 PRINT 110, J, (TN(I,J),I=L,LL )
  ISN 00075              IF (CONT(2).NE.CP) GO TO 77
  ISN 00076              CALL TNOUT (MPRINT,NPRINT,MCAL,NCAL,TNS,RIS,PHIS,XX,YY,ZZ,ZYJ,
                        1            ZIIJ,ZII )
  ISN 00077           77 CONTINUE
  ISN 00078              DO 95 L=1,M,11
  ISN 00079              IF (L+10.GT.M+1) GO TO 78
  ISN 00080              LL = L+10
  ISN 00081              GO TO 79
  ISN 00082           78 LL = M+1
  ISN 00083           79 CONTINUE
  ISN 00084              PRINT 101, RADA,RMAX,M,N,OMEGA,ERROR,ITERA,ITEP,OMPSI
  ISN 00085              PRINT 200, (I,I=L,LL )
  ISN 00086              DO 95 J=1,N+1
  ISN 00087           95 PRINT 210, J, (PSI(I,J),I=L,LL )
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ISN 00088            IF (CONT(3).NE.CP) GO TO 96
ISN 00089            CALL  PSIOUT (MPRINT,NPRINT,MCAL,NCAL,PSIS,RIS,PHIS,XXP,YYP,
                    1              ZZP,ZYJP, ZIIJP,ZIIP )
ISN 00090         96 CONTINUE
               C                   U(I,J) PRINT OUT
ISN 00091            DO 320 L=1,M,11
ISN 00092            IF (L+10.GT.M+1) GO TO 300
ISN 00093            LL = L+10
ISN 00094            GO TO 310
ISN 00095        300 LL = M+1
ISN 00096        310 CONTINUE
ISN 00097            PRINT 101, RADA,RMAX,M,N,OMEGA,ERROR,ITERA,ITEP,OMPSI
ISN 00098            PRINT 400
ISN 00099            PRINT 410, (I,I=L,LL)
               C
ISN 00100            DO 320 J=1,N+1
ISN 00101        320 PRINT 110, J, (U(I,J),I=L,LL)
               C
               C                   V(I,J) PRINT OUT
ISN 00102            DO 350 L=1,M,11
ISN 00103            IF (L+10.GT.M+1) GO TO 330
ISN 00104            LL = L+10
ISN 00105            GO TO 340
ISN 00106        330 LL = M+1
ISN 00107        340 CONTINUE
ISN 00108            PRINT 101, RADA,RMAX,M,N,OMEGA,ERROR,ITERA,ITEP,OMPSI
ISN 00109            PRINT 420
ISN 00110            PRINT 410, (I,I=L,LL)
               C
ISN 00111            DO 350 J=1,N+1
ISN 00112        350 PRINT 110, J, (V(I,J),I=L,LL)
               C                   CALCULATION OF INERTIA
ISN 00113            CALL INERTA
               C
               C                   SBYU(I,J) PRINT OUT
ISN 00114            DO 450 L=1,M,11
ISN 00115            IF (L+10.GT.M+1) GO TO 430
ISN 00116            LL = L+10
ISN 00117            GO TO 440
ISN 00118        430 LL = M+1
ISN 00119        440 CONTINUE
ISN 00120            PRINT 101, RADA,RMAX,M,N,OMEGA,ERROR,ITERA,ITEP,OMPSI
ISN 00121            PRINT 500
ISN 00122            PRINT 410, (I,I=L,LL)
               C
ISN 00123            DO 450  J=1,N+1
ISN 00124        450 PRINT 110, J,  (SBYU(I,J), I=L,LL)
               C
               C
               C                   EFFECTIVE AND MOLECULAR CONDUCTIVITY RATIO
               C
ISN 00125            DO 90 J=1,N+1
ISN 00126            DTDRI(J) = (-25.*TN(1,J)+48.*TN(2,J)-36.*TN(3,J)+16.*TN(4,J)
                    1           -3.*TN(5,J))/(12.*DR)
ISN 00127            EKBYK(J) = -DTDRI(J)*ALOG(RMAX)
ISN 00128            DTDRO(J) = (25.*TN(M+1,J)-48.*TN(M,J)+36.*TN(M-1,J)-16.*TN(M-2,J)
                    1           +3.*TN(M-3,J))/(12.*DR)
ISN 00129            EKBYKO(J)= -DTDRO(J)*RMAX*ALOG(RMAX)
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ISN 00130        90 CONTINUE
ISN 00131           DPS = DPH
ISN 00132           CALL  SIMPSN (N+1,DPS,EKBYK,SEKBYK,IER1)
ISN 00133           CALL  SIMPSN (N+1,DPS,EKBYKO,SEKBKO,IER)
ISN 00134           AVNUSS = SEKBYK/3.1415926
ISN 00135           AVNUSO = SEKBKO/3.1415926
               C
ISN 00136           PRINT 111, AVNUSS,RADA, RMAX
ISN 00137           PRINT 121, (J,EKBYK(J), J=1,N+1)
               C
ISN 00138           PRINT 115, AVNUSO,RADA,RMAX
ISN 00139           PRINT 121, (J,EKBYKO(J), J=1,N+1 )
               C                     RELATIVE LOCAL HEAT FLUX
               C
ISN 00140           DO 98 J=1,N+1
ISN 00141           QIBYQM(J) = EKBYK(J) /AVNUSS
ISN 00142        98 QOBYQM(J) = EKBYKO(J)/AVNUSO
               C
ISN 00143           PRINT 122
ISN 00144           PRINT 121, (J,QIBYQM(J), J=1,N+1)
ISN 00145           PRINT 123
ISN 00146           PRINT 121, (J,QOBYQM(J), J=1,N+1)
ISN 00147           IF (CONT(4).NE.CP) GO TO 241
ISN 00148           CALL VISUAL (RIS,PHIS,TNS,M+1,N+1,XX,YY,ZZ,ZYJ,ZIIJ,ZII,KZ,NZ,OPT)
ISN 00149           PRINT 250
ISN 00150       241 CONTINUE
ISN 00151           IF (CONT(5).NE.CP) GO TO 242
               C
ISN 00152           CALL VISUAL (RIS,PHIS,PSIS,M+1,N+1,XX,YY,ZZ,ZYJ,ZIIJ,ZII,KZ,
                  1                  NZ,OPT)
ISN 00153           PRINT 260
ISN 00154       242 IF (CONT(8).NE.CP) GO TO 243
ISN 00155           CALL VISUAL(RIS,PHIS,ZETA,M+1,N+1,XX,YY,ZZ,ZYJ,ZIIJ,ZII,KZ,NZ,OPT)
ISN 00156           PRINT 265
ISN 00157       243 CONTINUE
ISN 00158           IF (CONT(9).NE.CP) GO TO 245
ISN 00159           CALL VISUAL(RIS,PHIS,SBYU,M+1,N+1,XX,YY,ZZ,ZYJ,ZIIJ,ZII,KZ,NZ,OPT)
ISN 00160           PRINT 266
ISN 00161       245 CONTINUE
ISN 00162           RADAS = RADA
ISN 00163           IF (CONT(6).NE.CP) GO TO 270
ISN 00164           CALL PLDATA  (RIS,PHIS,TNS,M+1,N+1,RMAX)
ISN 00165       270 CONTINUE
               C
ISN 00166           IF (CONT(7).NE.CP) GO TO 280
ISN 00167           CALL PLDATA  (RIS,PHIS,PSIS,M+1,N+1,RMAX)
ISN 00168       280 CONTINUE
               C
               C                     INPUT FORMATS
ISN 00169         1 FORMAT ( 5I10)
ISN 00170         2 FORMAT ( 5F5.0)
ISN 00171         3 FORMAT ( 20A1,A4,T30, A4)
               C
               C                     ALARM MESSAGES
ISN 00172        65 FORMAT ('1', // T20,'CONVERGENCE OF TN(I,J) ARE NOT ACHIEVED' /
                  1                    T20,' NUMBER OF ITERATION(ITERA) =', I6, /
                  2                    T20,' RESULTS AFTER LATEST ITERATION ARE AS FLLOWS
                  3'/T20, ' OMEGA =', 1PD13.4/ T20, 'EPS  =', 1PE13.4 /)
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18        MAIN  DATE 83.01.17  TIME 14.02.20

                  C
                  C                         OUTPUT FORMATS
ISN 00173           100 FORMAT (    //T45, 'SOLUTION OF D-LESS TEMPERATUR DISTRIBUTION '/
                      1        //  T13, 11( 'I =', I3, 5X ) )
ISN 00174           101 FORMAT ('1'/ T2,'RADA =',1PE8.1,T18,'RO/RI =',0PF5.2,T32,'M =',I3,
                      1        T40,'N =',I3,T48,'OMEGA =',1PE11.4,T68,'ERROR =',1PE10.3,
                      2        T87, 'ITERA =',I4,T101,'ITEP =',I4,T113,'OMPSI =',1PE11.4 )
                  C
ISN 00175           110 FORMAT (/ T3,'J=', I3, T10, 1P11D11.3   )
                  C
ISN 00176           111 FORMAT ( '1' // T47,  'EFFECTIVE CONDUCTIVITY ON INNER WALL'
                      A              // T20, 'AVNUSS = ', 1PE15.3, T50,'RADA = ',1PE15.3,
                      1                 T80, 'RMAX = ', 1PE15.3, // T5, 9( 'J',4X,'KE/K',
                      2                 5X )  / )
ISN 00177           115 FORMAT (   /// T47,  'EFFECTIVE CONDUCTIVITY ON OUTER WALL'
                      A              // T20, 'AVNUSO = ', 1PE15.3, T50,'RADA = ',1PE15.3,
                      1                 T80, 'RMAX = ', 1PE15.3, // T5, 9( 'J',4X,'KE/K',
                      2                 5X )  / )
                  C
ISN 00178           121 FORMAT ( 9(I6,    F8.4 ) /)
ISN 00179           122 FORMAT (// T46, 'RELATIVE LOCAL HEAT FLUX AT INNER WALL' //
                      1            T5,  9( 'J', 3X, 'Q(J)/QM',    3X)  / )
ISN 00180           123 FORMAT (// T46, 'RELATIVE LOCAL HEAT FLUX AT OUTER WALL' //
                      1            T5,  9( 'J', 3X, 'Q(J)/QM',    3X)  / )
ISN 00181           200 FORMAT (    //T45, 'SOLUTION OF D-LESS STREAM FUNCTION' ///
                      1               T13, 11( 'I =', I3, 5X ) )
                  C
ISN 00182           210 FORMAT (/ T3,'J=', I3, T10, 1P11D11.3    )
ISN 00183           230 FORMAT ( '1',//  T20, ' TN(I,J) AND PSI(I,J) ARE CONVERGED.', //
                      1                  T20, ' ITERA = ',  I4,  T50, '(TEMP-LOOP)',
                      2                / T20, ' ITEP = ',  I4,  T50,  '(PSI-LOOP)',
                      3                / T20,  '    EPS   = ', 1PE13.4,T50, '(TEMP ERROR)',
                      4                / T20,  ' ERRPSI= ', 1PE13.4,T50, '(PSI-ERROR)'/ )
ISN 00184           240 FORMAT (  T10, 'ITERA =', I4,  T24, 'ITEP =', I4, T37,
                      1            'APS =',1PE13.4, T61, 'ERRPSI =', 1PE13.4,
                      2            T85,  'OMEGA =', 1PE13.4, T110, 'OMPSI =', 1PE13.4 )
                  C
                  C
ISN 00185           250 FORMAT (///T47, ' NORMALIZED TEMPERATURE DISTRIBUTION ' )
ISN 00186           260 FORMAT (///T45, ' NORMALIZED STREAM FUNCTION DISTRIBUTION ')
ISN 00187           265 FORMAT (///T57, ' VORTICITY '  )
ISN 00188           266 FORMAT (///T59, ' INERTIA ' )
                  C
ISN 00189           400 FORMAT (// T48, 'DIMENSIONLESS RADIAL VELOCITY U(I,J)' )
ISN 00190           410 FORMAT ( /// T13, 11('I =', I3, 5X) )
ISN 00191           420 FORMAT ( // T43, 'DIMENSIONLESS CIRCUMFERENTIAL VELOCITY V(I,J)')
ISN 00192           500 FORMAT ( // T46, 'DIMENSIONLESS INERTIA SBYU(I,J)*(PR)/(DA) ' )
                  C
ISN 00193               STOP
ISN 00194               END
```

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SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)
   ISN 00001          SUBROUTINE PTSNGL(TN,PSI,RI,PHI,TNS,PSIS,RIS,PHIS,MCAL,NCAL)          00033900
   ISN 00002          DOUBLE PRECISION TN,PSI,RI,PHI                                        00034000
   ISN 00003          DIMENSION TN(41,41),PSI(41,41),RI(41),PHI(41),TNS(MCAL,NCAL),         00034100
                     1         PSIS(MCAL,NCAL),RIS(MCAL),PHIS(NCAL)                          00034200
   ISN 00004          DO 10 IR=1,MCAL                                                       00034300
   ISN 00005          DO 10 JP=1,NCAL                                                       00034400
   ISN 00006          TNS(IR,JP)=TN(IR,JP)                                                  00034500
   ISN 00007          PSIS(IR,JP)=PSI(IR,JP)                                                00034600
   ISN 00008          RIS(IR)=RI(IR)                                                        00034700
   ISN 00009       10 PHIS(JP)=PHI(JP)                                                      00034800
   ISN 00010          RETURN                                                                00034900
   ISN 00011          END                                                                   00035000
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FACOM OSIV/F4 FORTRAN IV (HE)   V04L18            DATE 83.01.17  TIME 14.02.21

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

ISN 00001            SUBROUTINE TNOUT (MM,NN,MCAL,NCAL,TNS,RIS,PHIS,XX,YY,ZZ,ZYJ,ZIIJ,
                    1                  ZII )
               C
               C
ISN 00002            COMMON/SORCO/ OMEGA,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,OMPSI
ISN 00003            COMMON/TNPSI/ TN( 41, 41),PSI( 41, 41),RADA
ISN 00004            COMMON/RPHIC/ RMIN,RMAX,PHMIN,PHMAX
               C
ISN 00005            DOUBLE PRECISION TN,OMEGA,DR,RI,DPH,RADA,PHI,PSI
ISN 00006            DOUBLE PRECISION  OMPSI
               C
               C
ISN 00007            DIMENSION TNS(MCAL,NCAL),RIS(MCAL), PHIS(NCAL), XX(MM), YY(NN),
                    1          ZZ(MM,NN), ZYJ(MCAL), ZIIJ(MM,NCAL), ZII(NCAL)
               C
ISN 00008            CALL D2ITPL( RIS,PHIS,TNS,MCAL,NCAL,XX,YY,ZZ,MM,NN,IERO,ZYJ,ZIIJ,
                    1              ZII )
ISN 00009            IF ( IERO.EQ.0 ) GO TO 20
ISN 00010            PRINT 100
ISN 00011            STOP
ISN 00012         20 CONTINUE
ISN 00013            DO 40 L=1,MM,11
ISN 00014            IF ( L+11.GT.MM ) GO TO 25
ISN 00015            LL = L+10
ISN 00016            GO TO 30
               C
ISN 00017         25 LL = MM
ISN 00018         30 CONTINUE
               C
               C
ISN 00019            PRINT 150,RADA,RMAX,RMIN,PHMAX,PHMIN,MCAL,NCAL,ITERA,EPS
ISN 00020            PRINT 160
ISN 00021            PRINT 200,( XX(IR), IR=L,LL)
ISN 00022            DO 40 JP=1,NN
ISN 00023            YYDEG  =  YY(JP)*180./3.1415926
ISN 00024         40 PRINT 300, YY(JP),YYDEG,(ZZ(IR,JP),IR=L,LL)
ISN 00025            RETURN
               C
               C         ERROR MESSAGE
ISN 00026        100 FORMAT ( // T20, 'ERROR HAPPENED IN TNOUT (D2ITPL) ' // )
               C
               C         OUTPUT FORMAT
ISN 00027        150 FORMAT ('1', //  T10, 'RADA = ', 1PD10.3, T30, 'RMAX = ', 1PE10.3,
                    1          T50, 'RMIN = ', 1PE10.3, T70, 'PHMAX = ', 1PE10.3, T90,
                    2          'PHMIN = ', 1PE10.3 //   T10, 'MCAL =', I4, '(R-MESH)',
                    3          T30, 'NCAL =', I4, '(PHI-MESH)', T70, 'ITERA =', I8,
                    4          T90, 'EPS   = ', 1PE10.3 / )
ISN 00028        160 FORMAT (T46, 'TABLE OF INTERPOLATED TEMPERATURE DISTRIBUTION' /
                    1          T46, 46('-')  //
                    2          T5,  '(YY)', T11, 11(7X,'(XX)' )  /
                    3          T5,  'PHI(DEG)', T19, 'R =', T22, 10(8X, 'R =')    )
ISN 00029        200 FORMAT (  T15, 1P11E11.3 / )
ISN 00030        300 FORMAT ( / T2,F5.3, '(', F5.1, ')',  T15,1P11E11.3    )
               C
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.17  TIME 14.02.21

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001             SUBROUTINE PSIOUT (MM,NN,MCAL,NCAL,PSIS,RIS,PHIS,XXP,YYP,ZZP,
                       1                      ZYJP, ZIIJP,ZIIP )
                  C
                  C
                  C
                  C
  ISN 00002             COMMON/RPHIC/ RMIN,RMAX,PHMIN,PHMAX
  ISN 00003             COMMON/TNPSI/ TN( 41, 41),PSI( 41, 41),RADA
  ISN 00004             COMMON/SORCO/ OMEGA,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,OMPSI
  ISN 00005             DOUBLE PRECISION TN,OMEGA,DR,RI,DPH,RADA,PHI,PSI
  ISN 00006             DOUBLE PRECISION  OMPSI
  ISN 00007             DIMENSION PSIS(MCAL,NCAL), RIS(MCAL), PHIS(NCAL), XXP(MM), YYP(NN)
                       1,          ZZP(MM,NN), ZYJP(MCAL), ZIIJP(MM,NCAL), ZIIP(NCAL)
                  C
  ISN 00008             CALL D2ITPL (RIS,PHIS,PSIS,MCAL,NCAL,XXP,YYP,ZZP,MM,NN,IERP,ZYJP,
                       1                ZIIJP,ZIIP )
  ISN 00009             IF ( IERP.EQ.0 ) GO TO 20
  ISN 00010             PRINT 100
  ISN 00011             STOP
  ISN 00012          20 CONTINUE
  ISN 00013             DO 40 L=1,MM,11
  ISN 00014             IF ( L+11.GT.MM ) GO TO 25
  ISN 00015             LL = L+10
  ISN 00016             GO TO 30
                  C
  ISN 00017          25 LL = MM
  ISN 00018          30 CONTINUE
                  C
  ISN 00019             PRINT 150, RADA,RMAX,RMIN,PHMAX,PHMIN,MCAL,NCAL,ITERA,ERRPSI
  ISN 00020             PRINT 160
  ISN 00021             PRINT 200, (XXP(IR), IR=L,LL )
                  C
  ISN 00022             DO 40 JP=1,NN
  ISN 00023             YYDEG  =    YYP(JP)*180.0/3.1415926
  ISN 00024          40 PRINT 300, YYP(JP),YYDEG,(ZZP(IR,JP),IR=L,LL)
  ISN 00025             RETURN
                  C                        ERROR MESSAGE
  ISN 00026         100 FORMAT ( // T20, 'ERROR HAPPENED IN PSIOUT (D2ITPL) ' // )
                  C
                  C                        OUTPUT FORMATS
  ISN 00027         150 FORMAT ( '1' // T10, 'RADA = ', 1PD10.3, T30, 'RMAX = ', 1PE10.3,
                       1         T50,'RMIN = ', 1PE10.3,T70, 'PHMAX = ', 1PE10.3, T90,
                       2         'PHMIN = ', 1PE10.3, // T10, 'MCAL = ', I4, '(R-MESH)',
                       3         T30, 'NCAL =', I4, '(PHI-MESH)', T70, 'ITERA =', I8,
                       4         T90, 'ERRPSI =', 1PE10.3                 /)
  ISN 00028         160 FORMAT ( / T50, 'TABLE OF INTERPOLATED STREAM FUNCTION' / T50,
                       1 37('-')//T5,'(YYP)',   T11, 11( 6X, '(XXP)')   / T5, 'PHI(DEG)',
                       2        T19, 'R =', T22, 10( 8X, 'R =')    )
  ISN 00029         200 FORMAT (  T15,  1P11E11.3 /  )
  ISN 00030         300 FORMAT (/T2, F5.3, '(', F5.1, ')',  T15, 1P11E11.3  )
                  C
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SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

   ISN 00001            SUBROUTINE VELOCI
   ISN 00002            COMMON/INTEC/ M,N,MCAL,NCAL
   ISN 00003            COMMON/TNPSI/ TN( 41, 41),PSI( 41, 41),RADA
   ISN 00004            COMMON/VELCO/ U( 41, 41),V( 41, 41)
   ISN 00005            COMMON/INDEP/ RI( 41),PHI( 41),DR,DPH
   ISN 00006            DOUBLE PRECISION PSI,RI,DR,DPH,TN,RADA,PHI
   ISN 00007            DOUBLE PRECISION U,V
   ISN 00008            DO 10 J=1,N+1
   ISN 00009            DO 10 I=1,M+1
   ISN 00010            IF (J.EQ.1)    GO TO 1
   ISN 00011            IF (J.EQ.N+1) GO TO 2
   ISN 00012            U(I,J) = (PSI(I,J+1)-PSI(I,J-1)) / (2.0*RI(I)*DPH)
   ISN 00013            GO TO 3
                  C
   ISN 00014          1 U(I,J) = (PSI(I,J+1)-PSI(I,J)) / (RI(I)*DPH)
   ISN 00015            GO TO 3
                  C
   ISN 00016          2 U(I,J) = (PSI(I,J)-PSI(I,J-1)) / (RI(I)*DPH)
                  C
   ISN 00017          3 IF (I.EQ.1)    GO TO 4
   ISN 00018            IF (I.EQ.M+1) GO TO 5
   ISN 00019            V(I,J) = (PSI(I-1,J)-PSI(I+1,J)) / (2.0*DR)
   ISN 00020            GO TO 10
                  C
   ISN 00021          4 V(I,J) = (PSI(I,J)-PSI(I+1,J)) / DR
   ISN 00022            GO TO 10
   ISN 00023          5 V(I,J) = (PSI(I-1,J)-PSI(I,J)) / DR
   ISN 00024         10 CONTINUE
   ISN 00025            RETURN
   ISN 00026            END
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.17  TIME 14.02.22

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001            SUBROUTINE VORTIC(RADA,TN, DR,RI,PHI,DPH,MCAL,NCAL,ZETA)
                 C
                 C         RADA      RA * DA
                 C         TNS       TEMPERATURE
                 C         DR        RADIAL MESH SIZE
                 C         RI        RADIUS
                 C         PHI       ANGLE FROM BOTTOM CENTER      (RAD)
                 C         DPH       ANGULAR MESH SIZE
                 C         ZETA      VORTICITY
                 C
  ISN 00002            DIMENSION  TN(MCAL,NCAL),RI(MCAL),PHI(NCAL),ZETA(MCAL,NCAL)
  ISN 00003            DOUBLE PRECISION RADA,    DR,RI,PHI,DPH,D,E
                 C
  ISN 00004            DO 60 J=1,NCAL
  ISN 00005            DO 60 I=1,MCAL
  ISN 00006            IF (J.EQ.1)    GO TO 10
  ISN 00007            IF (J.EQ.NCAL) GO TO 20
                 C
  ISN 00008            E = (TN(I,J+1)-TN(I,J-1))/(2.*DPH*RI(I))*DCOS(PHI(J))
  ISN 00009            GO TO 30
  ISN 00010         10 E = (TN(I,2)-TN(I,1))/(DPH*RI(I))*DCOS(PHI(J))
  ISN 00011            GO TO 30
  ISN 00012         20 E = (TN(I,NCAL)-TN(I,NCAL-1))/(RI(I)*DPH)*DCOS(PHI(J))
                 C
  ISN 00013         30 IF (I.EQ.1)    GO TO 40
  ISN 00014            IF (I.EQ.MCAL) GO TO 50
  ISN 00015            D = (TN(I+1,J)-TN(I-1,J))/(2.0*DR)*DSIN(PHI(J))
  ISN 00016            GO TO 60
  ISN 00017         40 D = (TN(2,J)-TN(1,J))/DR*DSIN(PHI(J))
  ISN 00018            GO TO 60
  ISN 00019         50 D = (TN(MCAL,J)-TN(MCAL-1,J))/DR*DSIN(PHI(J))
                 C
                 C
  ISN 00020         60 ZETA(I,J) = -RADA * (D+E)
                 C
  ISN 00021            RETURN
  ISN 00022            END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18             DATE 83.01.17  TIME 14.02.22

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001             SUBROUTINE PSISOL
                  C
                  C     THIS ROUTINE SOLVES EQ. OF MOTION IN HORIZONTAL ANNULAR POROUS
                  C     MEDIA BY EXTRAPOLATED LIEBMANN METHOD
                  C                                          REVISED ON MARCH 1978
                  C
                  C         TN         DIMENSIONLESS TEMPERATURE AT MESH POINTS (I,J)
                  C         PSI        DIMENSIONLESS STREAM FUNCTION AT MESH POINTS (I,J)
                  C         OMPSI      RELAXATION FACTOR
                  C
  ISN 00002             COMMON/TNPSI/ TN( 41, 41),PSI( 41, 41),RADA
  ISN 00003             COMMON/SIGMA/ SNEW,SOLD,SPSI,SPSIO
  ISN 00004             COMMON/INDEP/ RI( 41),PHI( 41),DR,DPH
  ISN 00005             COMMON/INTEC/ M,N,MCAL,NCAL
  ISN 00006             COMMON/SORCO/ OMEGA,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,OMPSI
                  C
                  C
  ISN 00007             DOUBLE PRECISION TN,PSI,OMEGA,DR,RI,DPH,RADA,PHI,A,B,C,D,E,F,OMPSI
                  C
                  C
  ISN 00008             ITEP = 0
  ISN 00009           1 SPSI = 0.
  ISN 00010             SPSIO= 0.
                  C
  ISN 00011             DO 10 J=2,N
  ISN 00012             DO 10 I=2,M
  ISN 00013             A = 2.0/DR**2 + 2.0/(RI(I)*DPH)**2
  ISN 00014             B = (PSI(I+1,J)+PSI(I-1,J))/DR**2
  ISN 00015             C = (PSI(I+1,J) - PSI(I-1,J))/(2.0*RI(I)*DR)
  ISN 00016             D = (PSI(I,J+1)+PSI(I,J-1))/(RI(I)*DPH)**2
  ISN 00017             E = (TN(I+1,J)-TN(I-1,J))/(2.0*DR)*DSIN(PHI(J))
  ISN 00018             F = (TN(I,J+1)-TN(I,J-1))/(2.0*RI(I)*DPH)*DCOS(PHI(J))
                  C
  ISN 00019             SPSIO = SPSIO+PSI(I,J)
  ISN 00020             PSI(I,J) = (1.0-OMPSI)*PSI(I,J)+OMPSI/A*(B+C+D+RADA*(E+F))
  ISN 00021          10 SPSI = SPSI + PSI(I,J)
                  C
  ISN 00022             ITEP = ITEP+1
  ISN 00023             ERRPSI = ABS((SPSI-SPSIO)/SPSI)
  ISN 00024             IF (ITEP.GT.ITEL) GO TO 20
  ISN 00025             IF (ERRPSI.LT.ERROR) GO TO 30
                  C
  ISN 00026             GO TO 1
                  C
  ISN 00027          20 PRINT 100, ITERA,ITEP,ERRPSI,EPS
                  C
                  C
  ISN 00028             STOP
  ISN 00029          30 RETURN
                  C
  ISN 00030         100 FORMAT ( '1' // T20, ' PSI DOES NOT CONVERGE IN PSISOL '  //
                     1                T20, ' ITERA= ', I4          T50, '(TEMP-LOOP)'
                     2              / T20, ' ITEP = ', I4,         T50, '(PSI-LOOP) '
                     3              / T20, 'ERRPSI= ', 1PE13.4, T50, '(PSI-ERROR)'
                     4              / T20, '   EPS = ', 1PE13.4, T50, '(TEMP-ERROR)'/ )
                  C
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18           DATE 83.01.17  TIME 14.02.22

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

   ISN 00001                SUBROUTINE INERTA
                   C
                   C
   ISN 00002                COMMON/TNPSI/ TN(41,41),PSI(41,41),RADA
   ISN 00003                COMMON/INDEP/ RI(41),PHI(41),DR,DPH
   ISN 00004                COMMON/INTEC/ M,N,MCAL,NCAL
   ISN 00005                COMMON/VELCO/ U( 41, 41),V( 41, 41)
   ISN 00006                COMMON/INERC/ SAHEN(41,41),UHEN(41,41),SBYU(41,41)
                   C
   ISN 00007                DOUBLE PRECISION TN,PSI,RADA,RI,PHI,DR,DPH
   ISN 00008                DOUBLE PRECISION U,V
                   C
   ISN 00009                SBUMAX = 0.0
                   C
   ISN 00010                DO 1000 J = 1,N+1
   ISN 00011                DO 1000 I = 1,M+1
                   C
   ISN 00012                IF (I.EQ.1)   GO TO 15
   ISN 00013                IF (I.EQ.M+1) GO TO 10
                   C
                   C                   *** I = 2 TO M ***
   ISN 00014                D2PDR2 = (PSI(I-1,J)-2.*PSI(I,J)+PSI(I+1,J))/DR**2
   ISN 00015                D3R2DP = (RI(I-1)*U(I-1,J)-2.*RI(I)*U(I,J)+RI(I+1)*U(I+1,J))/DR**2
   ISN 00016                D2DRDP =(RI(I+1)*U(I+1,J)-RI(I-1)*U(I-1,J))/(2.*DR)
   ISN 00017                DTDR=(TN(I+1,J)-TN(I-1,J))/(2.*DR)
   ISN 00018                IF (I.EQ.M) GO TO 30
                   C
                   C                   *** I = 2 TO M-1 ***
   ISN 00019                D3PDR3 = (-PSI(I-1,J)+3.*PSI(I,J)-3.*PSI(I+1,J)+PSI(I+2,J))/DR**3
   ISN 00020                GO TO 50
                   C
                   C                   *** I = M+1 ***
   ISN 00021             10 ASIGN = -1.0
   ISN 00022                ISX = -1
   ISN 00023                GO TO 20
                   C
                   C                   *** I = 1 ***
   ISN 00024             15 ASIGN = 1.0
   ISN 00025                ISX = 1
                   C
                   C                   *** I = 1 OR M+1 ***
   ISN 00026             20 IX1 = ISX
   ISN 00027                IX2 = 2*ISX
   ISN 00028                IX3 = 3*ISX
   ISN 00029                IX4 = 4*ISX
                   C
   ISN 00030                D2PDR2 = ASIGN*(2.*PSI(I,J)-5.*PSI(I+IX1,J)+4.*PSI(I+IX2,J)
                          1             -1.*PSI(I+IX3,J))/DR**2
   ISN 00031                D3R2DP  =  ASIGN*(2.*RI(I)*U(I,J)-5.*RI(I+IX1)*U(I+IX1,J)
                          1        +4.*RI(I+IX2)*U(I+IX2,J)-RI(I+IX3)*U(I+IX3,J))/DR**2
   ISN 00032                D2DRDP  = ASIGN*(-RI(I)*U(I,J)+RI(I+IX1)*U(I+IX1,J))/DR
   ISN 00033                DTDR = ASIGN*(-TN(I,J)+TN(I+IX1,J))/DR
   ISN 00034                GO TO 40
                   C                   *** I = M ***
   ISN 00035             30 ASIGN = -1.0
   ISN 00036                IX1 = -1
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      INERTA  DATE 83.01.17  TIME 14.02.22

  ISN 00037          IX2 = -2
  ISN 00038          IX3 = -3
  ISN 00039          IX4 = -4
              C
              C                    *** I = 1 OR M OR M+1 ***
  ISN 00040       40 D3PDR3 = 0.5*ASIGN*(-5.*PSI(I,J)+18.*PSI(I+IX1,J)-24.*PSI(I+IX2,J)
                   1                 +14.*PSI(I+IX3,J)-3.*PSI(I+IX4,J))/DR**3
              C
              C                    *** J - LOOP ***
  ISN 00041       50 IF (J.EQ.1)    GO TO 65
  ISN 00042          IF (J.EQ.N+1) GO TO 60
              C
              C                    *** J = 2 TO N ***
  ISN 00043          D2PDP2 = (PSI(I,J-1)-2.*PSI(I,J)+PSI(I,J+1))/DPH**2
  ISN 00044          D3P2DR = -(V(I,J-1)-2.*V(I,J)+V(I,J+1))/DPH**2
  ISN 00045          DTDP = (TN(I,J+1)-TN(I,J-1))/(2.*DPH)
  ISN 00046          IF (J.EQ.N)    GO TO 80
              C
              C                    *** J = 2 TO N-1 ***
  ISN 00047          D3PDP3=(-PSI(I,J-1)+3.*PSI(I,J)-3.*PSI(I,J+1)+PSI(I,J+2))/DPH**3
  ISN 00048          GO TO 95
              C
              C                    *** J = N+1 ***
  ISN 00049       60 BSIGN = -1.0
  ISN 00050          JSX = -1
  ISN 00051          GO TO 70
              C
              C                    *** J = 1 ***
  ISN 00052       65 BSIGN = 1.0
  ISN 00053          JSX = 1
              C
              C                    *** J = 1 OR N+1 ***
  ISN 00054       70 JX1 = JSX
  ISN 00055          JX2 = 2*JSX
  ISN 00056          JX3 = 3*JSX
  ISN 00057          JX4 = 4*JSX
              C
  ISN 00058          D2PDP2 = BSIGN*(2.*PSI(I,J)-5.*PSI(I,J+JX1)+4.*PSI(I,J+JX2)
                   1                -PSI(I,J+JX3))/DPH**2
  ISN 00059          D3P2DR  =  -BSIGN*(2.*V(I,J)-5.*V(I,J+JX1)+4.*V(I,J+JX2)
                   1                    -V(I,J+JX3))/DPH**2
  ISN 00060          DTDP = BSIGN*(-TN(I,J)+TN(I,J+JX1))/DPH
  ISN 00061          GO TO 90
              C                    *** J = N ***
  ISN 00062       80 BSIGN = -1.0
  ISN 00063          JX1 = -1
  ISN 00064          JX2 = -2
  ISN 00065          JX3 = -3
  ISN 00066          JX4 = -4
              C
              C                    *** J = 1 OR N OR N+1 ***
  ISN 00067       90 D3PDP3 = 0.5*BSIGN*(-5.*PSI(I,J)+18.*PSI(I,J+JX1)-24.*PSI(I,J+JX2)
                   1                 +14.*PSI(I,J+JX3)-3.*PSI(I,J+JX4))/DPH**3
              C
              C                    *** LEFT TERM ***
  ISN 00068       95 S1 = U(I,J)*D3PDR3
  ISN 00069          S2 = V(I,J)*D3R2DP/RI(I)
  ISN 00070          S3 = V(I,J)*D3PDP3/RI(I)**3
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      INERTA  DATE 83.01.17  TIME 14.02.22

  ISN 00071          S4 = U(I,J)*D3P2DR/RI(I)**2
  ISN 00072          S5 = U(I,J)*D2PDR2/RI(I)
  ISN 00073          S6 = V(I,J)*D2DRDP/RI(I)**2
  ISN 00074          S7 = U(I,J)*V(I,J)/RI(I)**2
  ISN 00075          SAHEN(I,J) = S1 + S2 + S3 + S4 + S5 + S6 + S7
                C
  ISN 00076          U1 = D2PDR2 - V(I,J)/RI(I) + D2PDP2/RI(I)**2
  ISN 00077          U2 = RADA*(DTDR*DSIN(PHI(J)) + DTDP/RI(I)*DCOS(PHI(J)))
  ISN 00078          UHEN(I,J) = U1 + U2
  ISN 00079          IF (ABS(UHEN(I,J)).GT.0.0) GO TO 96
  ISN 00080          UHEN(I,J)=0.
  ISN 00081          SBYU(I,J)=0.
  ISN 00082          GO TO 1000
  ISN 00083       96 SBYU(I,J) = SAHEN(I,J)/UHEN(I,J)
                C
  ISN 00084          IF (SBYU(I,J).GT.SBUMAX) GO TO 100
  ISN 00085          GO TO 1000
                C
  ISN 00086      100 SBUMAX = SBYU(I,J)
  ISN 00087          ISUMAX = I
  ISN 00088          JSUMAX = J
  ISN 00089     1000 CONTINUE
                C
  ISN 00090          PRINT 1500
  ISN 00091     1500 FORMAT ('1'/// T10,10('*'),'RESULTS BY SUBROUTINE INERTA',10('*'))
                C
  ISN 00092          PRINT 2000, ISUMAX,JSUMAX,SAHEN(ISUMAX,JSUMAX),UHEN(ISUMAX,JSUMAX)
                    1,           SBYU(ISUMAX,JSUMAX)
                C
  ISN 00093     2000 FORMAT (     /// T10,'MAX INERTIA TERM POINT  I =', I3, 3X,'J =',
                    1            I3// T10,'SAHEN(I,J)  (INERTIA TERM) =',6X,E12.4//
                    2                 T10,'UHEN(I,J)  (BUOYANCY+DARCY)=',6X,E12.4//
                    3                 T10,'SBYU(I,J)  PR/DA*(SAHEN)/(UHEN)  =', E12.4/)
                C
  ISN 00094          RETURN
  ISN 00095          END
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.17  TIME 14.02.23

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001             SUBROUTINE SIMSOL
                  C
                  C     THIS ROUTINE SOLVES ENERGY AND MOTIONAL EQ. SIMULTANEOUSLY IN
                  C     HORIZONTAL ANNULAR POROUS MEDIA BY SUCCESSIVE OVER RELAXATION
                  C     METHOD WITH UPPER STREAM DIFFERENTIAL TECHNIQUE.
                  C
                  C        TN         DIMENSIONLESS TEMPERATURE AT MESH POINTS (I,J)
                  C        PSI        DIMENSIONLESS STREAM FUNCTION AT MESH POINTS (I,J)
                  C        OMEGA      RELAXATION FACTOR
                  C        U          DIMENSIONLESS RADIAL VELOCITY COMPONENT AT (I,J)
                  C        V          DIMENSIONLESS CIRCUMFERENTIAL VELOCITY COMPONENTS
                  C                   AT (I,J)
                  C
  ISN 00002             COMMON/SORCO/ OMEGA,ITERA,ITEL,ITEP,ERROR,ERRPSI,EPS,APS,OMPSI
  ISN 00003             COMMON/INTEC/ M,N,MCAL,NCAL
  ISN 00004             COMMON/INDEP/ RI( 41),PHI( 41),DR,DPH
  ISN 00005             COMMON/SIGMA/ SNEW,SOLD,SPSI,SPSIO
  ISN 00006             COMMON/TNPSI/ TN( 41, 41),PSI( 41, 41),RADA
  ISN 00007             COMMON/VELCO/ U( 41, 41),V( 41, 41)
                  C
                  C
  ISN 00008             DOUBLE PRECISION TN,PSI,OMEGA,DR,RI,DPH,RADA,PHI,A,B,C,D,E,F,OMPSI
  ISN 00009             DOUBLE PRECISION U,V
                  C
                  C                   DIMENSIONLESS VELOCITY
  ISN 00010             CALL VELOCI
  ISN 00011             SOLD = 0.0
  ISN 00012             SNEW = 0.0
                  C                   TEMPERATURE CALCULATION
                  C
  ISN 00013             DO 80 J=1,N+1
  ISN 00014             DO 80 I=2,M
                  C
  ISN 00015             IF (U(I,J).GT.0.0) GO TO 10
  ISN 00016             A = -U(I,J)/DR*RI(I)
  ISN 00017             E = -U(I,J)*TN(I+1,J)/DR*RI(I)
  ISN 00018             GO TO 20
                  C
  ISN 00019          10 A = U(I,J)/DR*RI(I)
  ISN 00020             E = U(I,J)*TN(I-1,J)/DR*RI(I)
                  C
  ISN 00021          20 IF (V(I,J).GT.0.0) GO TO 30
  ISN 00022             A = A - V(I,J)/DPH
  ISN 00023             F = -V(I,J)*TN(I,J+1)/DPH
  ISN 00024             GO TO 40
                  C
  ISN 00025          30 A = A + V(I,J)/DPH
  ISN 00026             F = V(I,J)*TN(I,J-1)/DPH
                  C
  ISN 00027          40 A = A + 2.0*RI(I)/DR**2 + 1.0/DR + 2.0/(RI(I)*DPH**2)
                  C
  ISN 00028             B = RI(I)*(TN(I+1,J)+TN(I-1,J))/DR**2
                  C
  ISN 00029             C = TN(I+1,J)/DR
                  C
  ISN 00030             IF (J.EQ.1)   GO TO 50
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18     SIMSOL  DATE 83.01.17  TIME 14.02.23

  ISN 00031          IF (J.EQ.N+1) GO TO 60
  ISN 00032          D = (TN(I,J+1)+TN(I,J-1))/(RI(I)*DPH**2)
  ISN 00033          GO TO 70
               C
  ISN 00034       50 D = 2.0*TN(I,2)/(RI(I)*DPH**2)
  ISN 00035          GO TO 70
               C
  ISN 00036       60 D = 2.0*TN(I,N)/(RI(I)*DPH**2)
               C
  ISN 00037       70 IF (J.EQ.1.OR.J.EQ.N+1) F = 0.0
               C
  ISN 00038          SOLD = SOLD + TN(I,J)
  ISN 00039          TO=TN(I,J)
  ISN 00040          TN(I,J) = (1.0-OMEGA)*TN(I,J) + OMEGA/A*(B+C+D+E+F)
  ISN 00041          IF (TN(I,J).LT.0.0)  GO TO 75
  ISN 00042          GO TO 80
  ISN 00043       75 PRINT 100, I,J,TN(I,J),A,B,C,D,E,F
  ISN 00044      100 FORMAT ( T2,'TSOL',T8,'I=',I2,'  J=',I2,'  TN=', 1PD11.3, '  A=',
                    1        1PD11.3, '  B=', 1PD11.3, '  C=', 1PD11.3, '  D=',1PD11.3,
                    2          '  E=', 1PD11.3, '  F=', 1PD11.3  )
  ISN 00045          X=TO*(1.0-OMEGA)
  ISN 00046          Y=OMEGA/A*(B+C+D+E+F)
  ISN 00047          PRINT 200, X,Y,TO,TN(I,J),ITERA
  ISN 00048          STOP'  TEMPERATURE IN SIMSOL IS ABNORMAL '
  ISN 00049      200 FORMAT ( T10, '(1.0-OMEGA)*TO = ',1PE13.3,T50,'OMEGA/A*(B+C+D+E+F)
                    1 = ', 1PE13.3, T90, 'TO =',1PE13.3, T110, 'TN =', 1PD13.3, T128,
                    2          'ITE=', I3  )
  ISN 00050       80 SNEW = SNEW + TN(I,J)
               C
  ISN 00051          CALL PSISOL
               C
  ISN 00052          RETURN
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18             DATE 83.01.17  TIME 14.02.23

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

 ISN 00001              SUBROUTINE VISUAL ( X,Y,Z,M,N,XA,YA,ZA,ZYJ,ZIIJ,ZII,KZ,NZ,OPT )
                 C
                 C      THIS ROUTINE VISUALIZE 3-DIMENSIONAL ARRAYS BY EASY METHOD.
                 C
                 C         X(I)    X-COORDINATE OF Z(I,J)  I=1,2, ... ,M
                 C         Y(J)    Y-COORDINATE OF Z(I,J)  J=1,2, ... ,N
                 C         Z(I,J) FUNCTION OF X(I),Y(J)  (VISUALIZING VALUES)
                 C
                 C      **REMARKS**
                 C        (1) X AND Y MUST BE MONOTONIC CHANGE AND EQ.-SPACES
                 C        (2) VISUALIZING PLANE IS 50 X 50  CHARACTERS
                 C        (3) X AND Y DIRECTION ARE HORIZONTAL AND VERTICAL RESPECTI-
                 C             VLY
                 C        (4) THIS ROUTINE NEEDS SUBROUTINE 'D2ITPL' AND 'INTPL2'
                 C        (5) IF OPT = 'SIMA', Z(I,J) WITHOUT EVEN NUMBERS ARE PRINTED.
                 C
 ISN 00002             ODIMENSION X(M),Y(N),Z(M,N),XA(50),YA(50),ZA(50,50),ZYJ(M),ZII(N),
                       1          ZIIJ(50,N),KZ(50,50),NZ(50,50)
                 C
 ISN 00003              DATA KBLANK,OPT1 / ' ','SIMA' /
                 C
 ISN 00004              CALL D2ITPL  (X,Y,Z,M,N,XA,YA,ZA,50,50,IERR,ZYJ,ZIIJ,ZII)
 ISN 00005              IF (IERR.EQ.0) GO TO 10
 ISN 00006              PRINT 1000
 ISN 00007              STOP
                 C
 ISN 00008           10 XAMAX = XA(1)
 ISN 00009              XAMIN = XA(1)
 ISN 00010              YAMAX = YA(1)
 ISN 00011              YAMIN = YA(1)
 ISN 00012              ZAMAX = ZA(1,1)
 ISN 00013              ZAMIN = ZA(1,1)
                 C
                 C
 ISN 00014              DO 20 I=2,50
 ISN 00015              IF (XA(I).GT.XAMAX) XAMAX = XA(I)
 ISN 00016              IF (XA(I).LT.XAMIN) XAMIN = XA(I)
 ISN 00017           20 CONTINUE
                 C
 ISN 00018              DO 30 J=2,50
 ISN 00019              IF (YA(J).GT.YAMAX) YAMAX = YA(J)
 ISN 00020              IF (YA(J).LT.YAMIN) YAMIN = YA(J)
 ISN 00021           30 CONTINUE
                 C
 ISN 00022              DO 40 J=1,50
 ISN 00023              DO 40 I=1,50
 ISN 00024              IF (ZA(I,J).GT.ZAMAX) ZAMAX = ZA(I,J)
 ISN 00025              IF (ZA(I,J).LT.ZAMIN) ZAMIN = ZA(I,J)
 ISN 00026           40 CONTINUE
                 C
                 C
                 C                        NORMALIZATION OF Z(I,J)
 ISN 00027              DO 50 J=1,50
 ISN 00028              DO 50 I=1,50
 ISN 00029              ZA(I,J) = (ZA(I,J)-ZAMIN)/(ZAMAX-ZAMIN)*1.1
 ISN 00030              IF (ZA(I,J).GE.1.1) ZA(I,J) = 1.0
```

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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18     VISUAL  DATE 83.01.17  TIME 14.02.23
   ISN 00031           ZA(I,J) = ZA(I,J)*10.0
   ISN 00032           KZ(I,J) = ZA(I,J) + 1
   ISN 00033           KZ(I,J) = KZ(I,J)*1000
   ISN 00034        50 CALL IBTOD(NZ(I,J),KZ(I,J))
                 C
   ISN 00035           IF (OPT.NE.OPT1) GO TO 55
   ISN 00036           DO 54 J=1,50
   ISN 00037           DO 54 I=1,50
   ISN 00038           KZA = (KZ(I,J)/2000)*2000
   ISN 00039        54 IF (KZA.EQ.KZ(I,J)) NZ(I,J)=KBLANK
   ISN 00040        55 CONTINUE
                 C
   ISN 00041           PRINT 1010, XAMAX,XAMIN
   ISN 00042           PRINT 1020, YAMAX,YAMIN
   ISN 00043           PRINT 1030, ZAMAX,ZAMIN
                 C
   ISN 00044           DO 60 J=1,50
   ISN 00045        60 PRINT 1040, (NZ(I,J), I=1,50)
                 C
                 C
   ISN 00046           RETURN
                 C
                 C
   ISN 00047      1000 FORMAT ( '1    ERROR HAPPENED IN SUBROUTINE VISUAL '  )
                 C
   ISN 00048      1010 FORMAT( '1' //  T10, 'XMAX =',1PE13.4 / T10, 'XMIN =',1PE13.4  )
                 C
   ISN 00049      1020 FORMAT (     T10,'YMAX =',1PE13.4 / T10, 'YMIN =',1PE13.4   )
   ISN 00050      1030 FORMAT (     T10,'ZMAX =',1PE13.4 / T10, 'ZMIN =',1PE13.4 / )
                 C
   ISN 00051      1040 FORMAT (  T40,   50A1    )
                 C
   ISN 00052           END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.17  TIME 14.02.24

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001              SUBROUTINE SIMPSN  (M,H,F,S,IER)
                   C
                   C         THIS ROUTINE INTEGRATES GIVEN FUNCTION F(1),F(2),...F(M) BY
                   C         SIMPSON METHOD.
                   C
                   C         M          NUMBER OF MESH POINTS  (M MUST BE ODD NUMBER)
                   C         H          MESH WIDTH OF INDEPENDENT VARIABLES  (EQ-SPASES)
                   C         F(I)       DIMENSION OF GIVEN FUNCTION  I=1,2,...,M
                   C         S          INTEGRATED VALUE OF FUNCTION
                   C         IER        ERROR CODE      =0   NORMAL
                   C                                    =1   ABNORMAL, S IS SET FOR S = 0.0
                   C
                   C
                   C
  ISN 00002              DIMENSION F(M)
                   C
  ISN 00003              MM = (M-1)/2*2
  ISN 00004              IF (MM.EQ.M-1) GO TO 10
  ISN 00005              IER = 1
  ISN 00006              S =.0.0
  ISN 00007              PRINT 100, IER,M
  ISN 00008              RETURN
                   C
  ISN 00009           10 N = (M-1)/2
  ISN 00010              S2 = 0.0
  ISN 00011              S4 = 0.0
                   C
  ISN 00012              DO 20 I=1,N
  ISN 00013              IF (I.EQ.N) GO TO 15
  ISN 00014              K2 = 2*I+1
  ISN 00015              S2 = S2+F(K2)
  ISN 00016           15 K4 = 2*I
  ISN 00017           20 S4 = S4+F(K4)
                   C
  ISN 00018              S = H*(F(1)+F(M)+4.0*S4+2.0*S2)/3.0
  ISN 00019              IER = 0
  ISN 00020              RETURN
  ISN 00021          100 FORMAT (/// T10, 10('*'), ' ERROR IN SUBROUTINE-SIMPSN ',10('*'),
                       1            / T10, 'M MUST BE ODD NUMBER  IER =',I2, '  M =',  I4 )
                   C
  ISN 00022              END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18             DATE 83.01.17  TIME 14.02.24

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001           SUBROUTINE  PLDATA (R,PHI,Z,M,N,RMAX)
                C
                C        THIS ROUTINE CHANGES POLAR COORDINATE TO RECTANGULAR
                C        COORDINATE AND WRITES X,Y,ZNORM DATA IN DISK FILE FOR GPCP-1
                C
                C
                C        R(I)        (I=1,2, ...,M)        RADIUS OF POLAR COORDINATE
                C        PHI(J)      (J=1,2, ...,N)        ANGLES OF POLAR COORDINATE
                C        Z(I,J)                            HEIGHT OF POINT R(I),PHI(J)
                C        ZNORM                             NORMALIZED Z(I,J)
                C        X                                 X COORDINATE OF R(I),PHI(J)
                C        Y                                 Y COORDINATE OF R(I),PHI(J)
                C
                C
  ISN 00002           DIMENSION  R(M),PHI(N),Z(M,N)
                C
  ISN 00003           ZMIN=Z(1,1)
  ISN 00004           ZMAX=Z(1,1)
                C
  ISN 00005           DO 10 J=1,N
  ISN 00006           DO 10 I=1,M
  ISN 00007           IF (Z(I,J).GT.ZMAX)  ZMAX=Z(I,J)
  ISN 00008        10 IF (Z(I,J).LT.ZMIN)  ZMIN=Z(I,J)
                C
  ISN 00009           DO 20 J=1,N
  ISN 00010           DO 20 I=1,M
  ISN 00011           ZNORM   =  (Z(I,J)-ZMIN)/(ZMAX-ZMIN)
  ISN 00012           X    =    R(I)*SIN(PHI(J))/RMAX
  ISN 00013           Y    =   -R(I)*COS(PHI(J))/RMAX
                C
                C
  ISN 00014           WRITE( 3,1040)  X,Y,ZNORM
  ISN 00015        20 CONTINUE
  ISN 00016           WRITE( 3,1045)
  ISN 00017           PRINT 1050
  ISN 00018      1040 FORMAT (          'CNTL'  T6, 3F10.5, T72, '2'  )
  ISN 00019      1045 FORMAT ( 'BEND' )
  ISN 00020      1050 FORMAT ( '1' // T10,  'X, Y, AND ZNORM ARE WRITTEN IN DISK FILE'/)
  ISN 00021           RETURN
  ISN 00022           END
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18              DATE 83.01.17  TIME 14.02.24

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)

  ISN 00001             SUBROUTINE INTPL2( A, B, X, Y, N, IERR )
                  C
                  C     THIS ROUTINE INTERPOLATES THE Y-VALUE TO THE X-VALUE  BY SECOND
                  C     ORDER INTERPOLATION.
                  C
                  C         A(N)        TABLE OF X(I),(I=1,2, , , ,N)
                  C         B(N)        TABLE OF Y(I),(I=1,2, , , ,N)   B(I)=FUNC(A(I))
                  C         X           GIVEN X
                  C         Y           Y-VALUE FOR X  (CALCULATED VALUE)
                  C         N           NUMBER(SIZE) OF POINTS IN TABLE
                  C         IERR        ERROR CODE
                  C
                  C             IERR=0   NORMAL CONDITION
                  C                 =2   VALUE OF X IS OUT-SIDE OF A(N) (MUST BE INSIDE)
                  C                 =3   A IS NOT UNIQUE
                  C
  ISN 00002             DIMENSION A(N),B(N)
                  C
  ISN 00003             DO 10 K=1,N
  ISN 00004             IF ( A(K).NE.X )  GO TO 10
  ISN 00005             Y=B(K)
  ISN 00006             IERR=0
  ISN 00007             RETURN
  ISN 00008          10 CONTINUE
                  C
  ISN 00009             IF ( N .GE. 3) GO TO 11
  ISN 00010             IERR = 1
  ISN 00011             RETURN
                  C
  ISN 00012          11 IERR = 0
  ISN 00013             OX = A(1)
  ISN 00014             IF ( A(N)-OX ) 31,12,21
  ISN 00015          12 IERR = 3
  ISN 00016             RETURN
                  C
  ISN 00017          21 IF ( X. LT. OX ) GO TO 19
                  C
  ISN 00018             DO 23 K=2,N
  ISN 00019             IF ( A(K) .LE. OX ) GO TO 12
  ISN 00020             OX = A(K)
  ISN 00021             IF ( X .LE. OX ) GO TO 100
  ISN 00022          23 CONTINUE
                  C
  ISN 00023          19 IERR = 2
  ISN 00024             RETURN
                  C
  ISN 00025          31 IF ( X .GT. OX ) GO TO 19
  ISN 00026             DO 33 K=2,N
  ISN 00027             IF ( A(K) .GE. OX ) GO TO 12
  ISN 00028             OX = A(K)
  ISN 00029             IF ( X .GE. OX ) GO TO 100
  ISN 00030          33 CONTINUE
  ISN 00031             GO TO 19
                  C
  ISN 00032         100 DX = OX - A(K-1)
  ISN 00033             IF (K .GT. 2 ) K=K-1
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      INTPL2  DATE 83.01.17  TIME 14.02.24

   ISN 00034          P = ( X-A(K) ) / DX                                                    00104400
   ISN 00035          Y = P*(1.+P)/2.*B(K+1) + (1.+P)*(1.-P)*B(K) - P*(1.-P)/2.*B(K-1)      00104500
   ISN 00036          RETURN                                                                 00104600
   ISN 00037          END                                                                    00104700
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18            DATE 83.01.17  TIME 14.02.24

SPECIFIED OPTIONS: NONAME,FLAG(I),BYNAME,GOSTMT,NOSTATIS,ISN(D),NOMAP,ELM(*)
   ISN 00001          SUBROUTINE  D2ITPL( X,Y,Z,M,N,XX,YY,ZZ,MM,NN,IERR,ZYJ,ZIIJ,ZII )
                C
                C       THIS ROUTINE TRANSFORMES 2-DIMENSIONAL ARRAY Z( X(I),Y(J) )
                C     TO  ZZ( XX(II),YY(JJ) ) IN THE SAME PLANE BY 2ND-ORDER INTERPOLA-
                C     TION.
                C      WHERE, I=1,2,,,  ,M    (M.GE.3)
                C             J=1,2,,,  ,N    (N.GE.3)
                C            II=1,2,,,  ,MM
                C            JJ=1,2,,,  ,NN
                C       X(I),Y(J),XX(II) AND YY(JJ) MUST BE PLACED IN SAME SPACES.
                C     ** THIS ROUTINE NEEDS SUBROUTINE INTPL2
                C       Z( X(I),Y(J) )          OLD 2-D ARRAY  (INPUT ARRAY)
                C       ZZ(XX(II),YY(JJ)        NEW 2-D ARRAY  (OUTPUT ARRAY)
                C       IERR                    ERROR CODE    IERR=0  GOOD CONDITION
                C                                             IERR=1  BAD  CONDITION
                C
                C       ZYJ(I)        AUX ARRAY
                C       ZIIJ(II,J)
                C       ZII(J)
   ISN 00002          DIMENSION X(M),Y(N),Z(M,N),XX(MM),YY(NN),ZZ(MM,NN),ZYJ(M),
                     1          ZIIJ(MM,N),ZII(N)
                C         MESH POINTS TRANSFORMATION
   ISN 00003          XL=X(M)-X(1)
   ISN 00004          YL=Y(N)-Y(1)
   ISN 00005          DO 10 II=1,MM
   ISN 00006       10 XX(II)=X(1)+XL*(II-1)/(MM-1)
   ISN 00007          DO 20 JJ=1,NN
   ISN 00008       20 YY(JJ)=Y(1)+YL*(JJ-1)/(NN-1)
                C
                C         X-COORDINATE PITCH TRANSFORMATION (INTERPOLATION)
   ISN 00009          DO 30 J=1,N
   ISN 00010          DO 25 I=1,M
   ISN 00011       25 ZYJ(I)=Z(I,J)
   ISN 00012          DO 30 II=1,MM
   ISN 00013          CALL INTPL2( X, ZYJ, XX(II), ZIIJ(II,J), M, IER1 )
   ISN 00014          IF ( IER1.EQ.0 ) GO TO 30
   ISN 00015          PRINT 100, IER1,J,II
   ISN 00016          IERR=1
   ISN 00017          RETURN
   ISN 00018       30 CONTINUE
                C
                C         Y-COORDINATE PITCH TRANSFORMATION
   ISN 00019          DO 40 II=1,MM
   ISN 00020          DO 35 J=1,N
   ISN 00021       35 ZII(J)=ZIIJ(II,J)
   ISN 00022          DO 40 JJ=1,NN
   ISN 00023          CALL INTPL2( Y, ZII, YY(JJ), ZZ(II,JJ), N, IER2 )
   ISN 00024          IF ( IER2.EQ.0 ) GO TO 40
   ISN 00025          PRINT 200, IER2, II,JJ
   ISN 00026          IERR=1
   ISN 00027          RETURN
   ISN 00028       40 CONTINUE
   ISN 00029          IERR=0
   ISN 00030      100 FORMAT ( ///  T20,'ERROR HAPPEND IN SUBROUTINE D2ITPL (X-PITCH INT
                     1ERPOLATION)',/T20,'ERROR CODE =',I5, T40,'REFER ITPL2' /
                     2              T20,'      J      =',I5, /
                     3              T20,'     II      =',I5   // )
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FACOM OSIV/F4 FORTRAN IV (HE)  V04L18      D2ITPL  DATE 83.01.17  TIME 14.02.24

              C
  ISN 00031       200 FORMAT ( ///  T20,'ERROR HAPPEND IN SUBROUTINE D2ITPL (Y-PITCH INT
                     1ERPOLATION)',/T20,'ERROR CODE =',I5, T40,'REFER ITPL2' /
                     2              T20,     'II     =',I5, /
                     3              T20,     'JJ     =',I5    // )
              C
  ISN 00032             RETURN
  ISN 00033             END
```