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JUNCTURE STRESS FIELDS IN MULTICELLULAR SHELL STRUCTURES

VOL. IV
STRESSES AND DEFORMATIONS OF FIXED-EDGE SEGMENTAL SPHERICAL SHELLS

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MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

SUMMARY

This report presents a set of basic equations for thin elastic spherical shells and a digital program for the analysis of the static response of segmental spherical shells with fixed edges under the following loading conditions:

- Uniform pressure
- Linear thermal gradient through the thickness of shell

The problem is solved numerically by means of finite-difference technique, using a direct method of solving a large system of simultaneous equations. A numerical example showing the stresses and deformations of a spherical sector under uniform pressure is also presented. For completeness as a self-contained report, much of the information presented in Vol. II is repeated here.

FOREWORD

This report is the result of a study on the numerical analysis of stresses and deformations of fixed-edge isotropic segmental spherical shells under uniform and hydrostatic pressures as well as linear thermal gradient across the thickness of the shell. Work on this study was performed by staff members of Lockheed Missiles & Space Company in cooperation with the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration under Contract NAS 8-11480. Contract technical representative was H. Coldwater.

This volume is the fourth of a nine-volume final report of studies conducted by the department of Solid Mechanics, Aerospace Sciences Laboratory, Lockheed Missiles & Space Company. Project Manager was K. J. Forsberg; E. Y. W. Tsui was Technical Director for the work.

The nine volumes of the final report have the following titles:

Vol. I	Numerical Methods of Solving Large Matrices
Vol. II	Stresses and Deformations of Fixed-Edge Orthotropic Segmental Cylindrical Shells
Vol. III	Stresses and Deformations of Fixed-Edge Segmental Conical Shells
Vol. IV	Stresses and Deformations of Fixed-Edge Segmental Spherical Shells
Vol. V	Influence Coefficients of Segmental Shells
Vol. VI	Analysis of Multicellular Propellant Pressure Vessels by the Stiffness Method
Vol. VII	Buckling Analysis of Segmental Orthotropic Cylinders Under Uniform Stress Distribution
Vol. VIII	Buckling Analysis of Segmental Orthotropic Cylinders Under Non-uniform Stress Distribution
Vol. IX	Summary of Results and Recommendations

CONTENTS

NOTATION

$a_i, b_i, c_i, A, B, C, \kappa$	nondimensional parameters defined in text
$D = E\hat{h}^3/12(1 - \nu^2)$	flexural rigidity of shell
E	modulus of elasticity
F_i	boundary force at Station i
F^f	boundary forces of fixed-edge shell due to applied forces or thermal gradients
G	shear modulus
$\hat{h}$	thickness of shell
$\bar{h}, \bar{k}$	mesh spacings in ϕ- and θ-coordinate directions
m, n	number of columns and rows of the mesh
i, j	dummy subscripts
k, k_{ij}	stiffness influence coefficients
$\hat{M}_{( )}, \hat{N}_{( )}$	moments and stress resultants
$p_{( )}$	surface or body forces
$\hat{Q}_{( )}$	transverse shears
R	radius of curvature
T	change of temperature from a zero thermal stress condition
$\hat{u}, \hat{v}, \hat{w}$	displacement components in directions ϕ, θ, and $\hat{z}$
$\phi, \theta, \hat{z}$	shell coordinates

α	coefficient of thermal expansion
ζ , η	orthogonal coordinates along boundaries of shell
δ_i	boundary deformations (displacements or rotations) at Station i
$\epsilon_{( )}$, $\gamma_{( )}$	direct and shear strains
$\hat{\chi}_{( )}$	changes of curvature or torsion of middle-surface
ν	Poisson's ratio
$\omega_{( )}$	rotations of the normal at the middle-surface
$( )_{,\phi}$	$\frac{\partial( )}{\partial\phi}$
$( )_i^j$	functions at a discrete point i , j where i , j implies the ϕ- and θ-directions respectively
Φ	rotation in the middle-surface around the normal

Additional notations and symbols are defined in the text.

Section 1
INTRODUCTION

As a result of an investigation of juncture stress fields peculiar to the multicellular pressure vessels (Fig. 1), a theory for the prediction of the membrane and bending stresses and the corresponding deformations for such shell structures was formulated.*

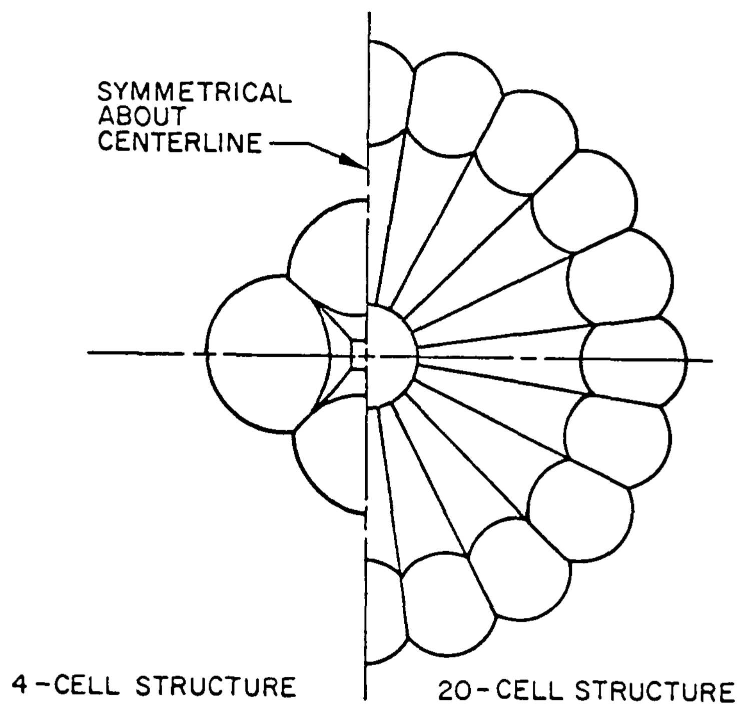

Fig. 1 Multicellular Shell Structure

*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 – NASA CR-61050.

Due to the fact that analytic solutions are still lacking, it was decided to solve the problem numerically by means of finite-difference technique. To ensure the feasibility of such a numerical solution, a direct method of solving large matrices with a high-speed digital computer was also developed.

According to the previous work, if the stiffness or displacement method is used, the total forces and hence the corresponding stresses along the juncture of the shell segments (Fig. 2) may be expressed concisely in the following matrix form

$$F = k\delta + F^f \qquad (1.1)$$

where k is the stiffness matrix; δ, the deformations; and F^f, the fixed-end forces due to applied loads or thermal gradients. In view of this situation, it is logical to solve the problem systematically by the established general procedure of analysis already described.* This procedure may be stated briefly as follows:

1. Determination of the fixed-end forces, F^f, along the boundary as well as stresses and deformations in the interior of shell segments due to loads
2. Determination of the influence coefficients, k_{ij}, along the boundaries of shell segments, i.e., the induced forces at points i due to unit deformations ($\delta = 1$) at points j
3. Determination of the actual deformations, δ, along the shell boundaries; this requires the satisfaction of both compatibility and equilibrium conditions at the junctures of the structure

Once all the work involved in these three steps is completed, the total stresses and deformations in the specific discrete interior locations may be obtained.

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*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 – NASA CR-61050.

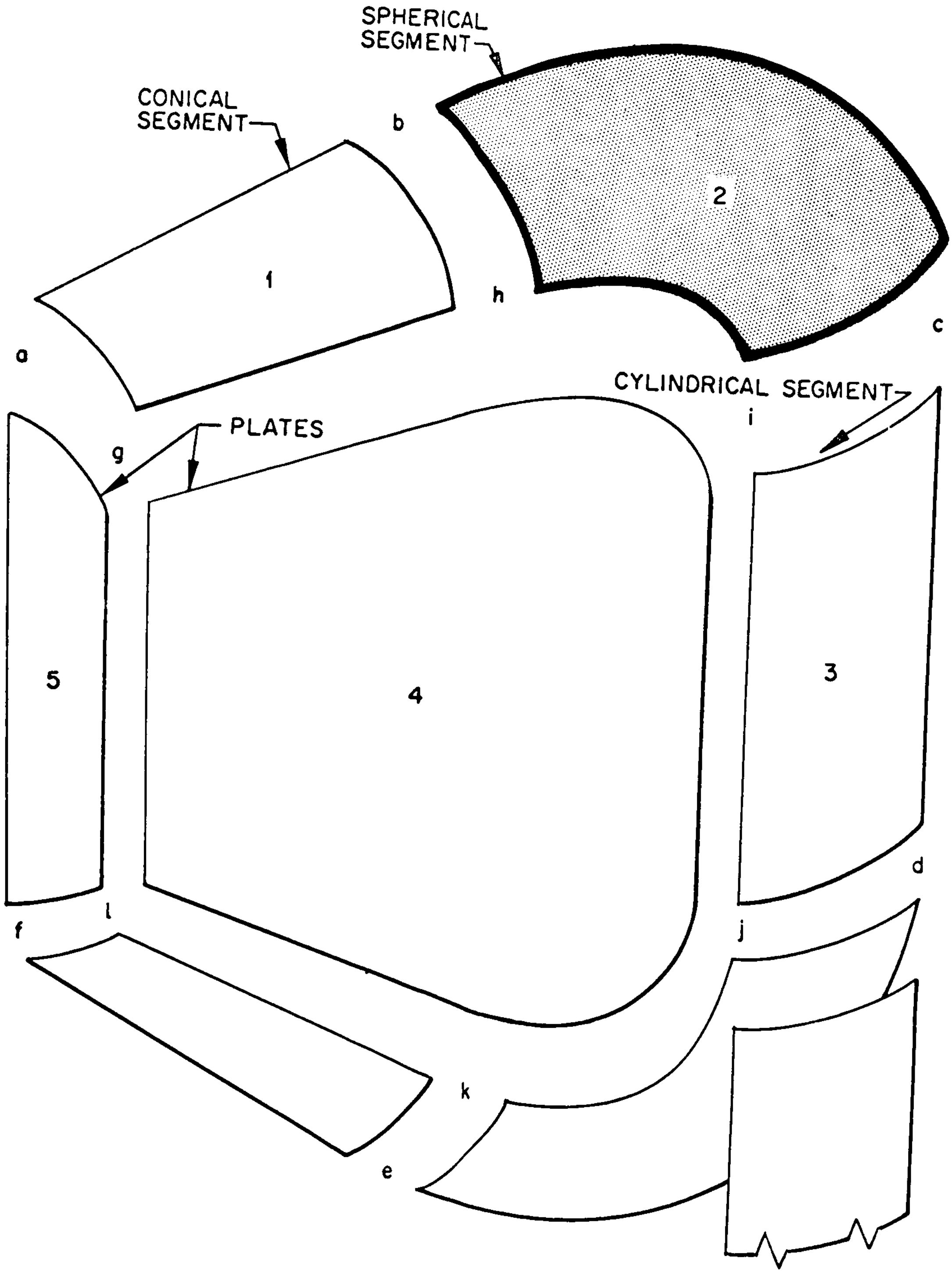

Fig. 2 Basic Shell Elements of Multicellular Structure

This volume presents results of the work involved in Step 1 only and covers the following items:

- Nondimensional formulation of the problem
- Detailed description of a workable digital program for the generation of solutions
- Example including tabulation of stresses and deformations of an isotropic spherical shell with fixed edges under uniform internal pressure

Section 2
FORMULATION OF THE PROBLEM

The necessary analytical expressions for a spherical shell have already been presented.* All the required equations are repeated in this report to make it a complete unit.

2.1 ANALYTICAL FORMULATION

The isotropic segmental spherical shell under consideration is of uniform thickness. It is bounded by a cylindrical panel, a segmental conical shell, and two radial plates as shown in Fig. 2. Only one half of the cell structure is shown in this figure because of the symmetry of the structure and the loading.

The geometry of the spherical segment is shown in Fig. 3. The orthogonal coordinates, ϕ and θ, can be oriented in a number of ways in the sphere so as to obtain a convenient description of the boundary curve. For example, in the orientation of Fig. 3 the intersection of the cylinder and sphere occurs at $\theta = 0$. It should be noted, however, that these coordinates are not parallel to all the intersections with the sphere.

In the formulation which follows the dependent variables and geometry have been nondimensionalized by the radius of curvature, R, as follows:

$$u = \frac{\hat{u}}{R} \tag{2.1a}$$

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*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 – NASA CR-61050.

$$v = \frac{\hat{v}}{R} \qquad (2.1b)$$

$$w = \frac{\hat{z}}{R} \qquad (2.1c)$$

$$z = \frac{\hat{z}}{R} \qquad (2.1d)$$

$$h = \frac{\hat{h}}{R} \qquad (2.1e)$$

Other nondimensional quantities will be defined as they are introduced. Note that the coordinates ϕ and θ have not been normalized.

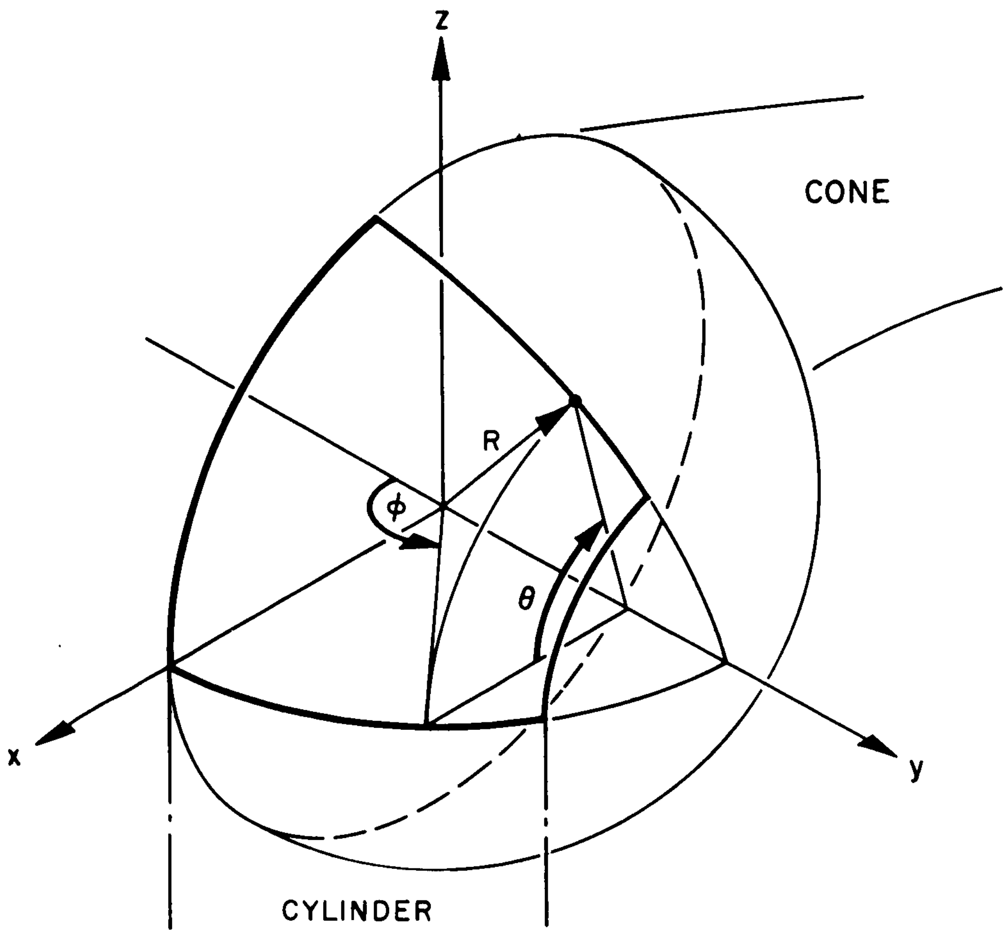


Fig. 3 Geometry of Segmental Spherical Shell

2.1.1 Rotation-Displacement Relations

Positive displacements and rotations of the middle-surface are shown in Fig. 4 and are related by equations:

$$\omega_\phi = u - w_{,\phi} \tag{2.2a}$$

$$\omega_\theta = v - \left(\frac{1}{\sin\phi}\right) w_{,\theta} \tag{2.2b}$$

$$\Phi = \frac{[v_{,\phi} - (1/\sin\phi) u_{,\theta} + \cot\phi\, v]}{2} \tag{2.2c}$$

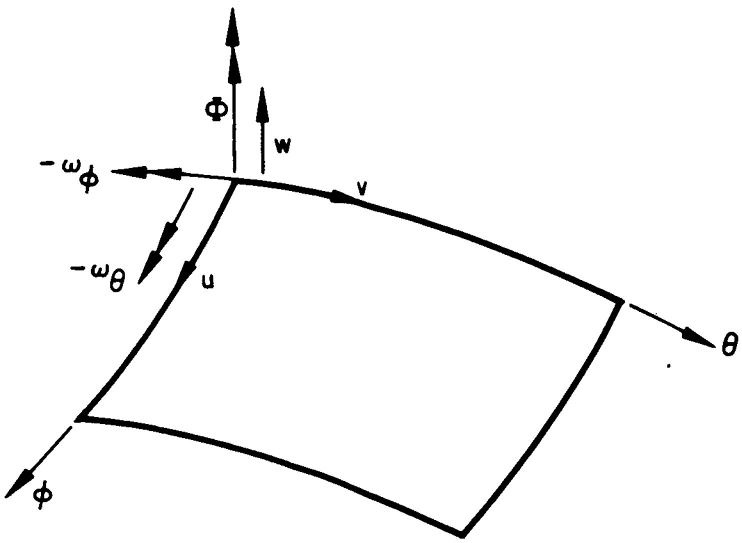


Fig. 4 Displacements and Rotations

2.1.2 Strain-Displacement Relations

The strains of the middle-surface are related to displacements by

$$\bar{\epsilon}_\phi = u_{,\phi} + w \tag{2.3a}$$

$$\bar{\epsilon}_{\theta} = \left(\frac{1}{\sin \phi}\right) v_{,\theta} + \cot \phi \, u + w \tag{2.3b}$$

$$\bar{\gamma}_{\phi\theta} = v_{,\phi} - \cot \phi \, v + \left(\frac{1}{\sin \phi}\right) u_{,\theta} \tag{2.3c}$$

and the changes of curvature and torsion are

$$\chi_{\phi} = [\hat{\chi}_{\phi} R] = u_{,\phi} - w_{,\phi\phi} \tag{2.4a}$$

$$\chi_{\theta} = [\hat{\chi}_{\theta} R] = \frac{[v_{,\theta} - (1/\sin \phi) w_{,\theta\theta} + (u - w_{,\phi}) \cos \phi]}{\sin \phi} \tag{2.4b}$$

$$\chi_{\phi\theta} = [\hat{\chi}_{\phi\theta} R] = \frac{[-w_{,\phi\theta} + \cot \phi \, w_{,\theta} + u_{,\theta} + \sin \phi \, v_{,\phi} - \cos \phi \, v]}{\sin \phi} \tag{2.4c}$$

The strains at a distance z from the middle-surface are

$$\epsilon_{\phi} = \bar{\epsilon}_{\phi} + z\chi_{\phi} \tag{2.5a}$$

$$\epsilon_{\theta} = \bar{\epsilon}_{\theta} + z\chi_{\theta} \tag{2.5b}$$

$$\gamma_{\phi\theta} = \bar{\gamma}_{\phi\theta} + 2z\chi_{\phi\theta} \tag{2.5c}$$

2.1.3 Constitutive Relations

Positive stress resultants are shown in Fig. 5. Nondimensional stress resultants are related to them and to strains by the following equations:

$$N_{\phi} = \left[\frac{\hat{N}_{\phi}(1 - \nu^2)}{E\hat{h}}\right] = \bar{\epsilon}_{\phi} + \nu\bar{\epsilon}_{\theta} + N^T \tag{2.6a}$$

$$N_\theta = \left[\frac{\hat{N}_\theta(1-\nu^2)}{E\hat{h}}\right] = \bar{\epsilon}_\theta + \nu\bar{\epsilon}_\phi + N^T \tag{2.6b}$$

$$N_{\theta\phi} = N_{\phi\theta} = \left(\frac{\hat{N}_{\phi\theta}}{\hat{h}G}\right) = \bar{\gamma}_{\phi\theta} + 2\kappa\chi_{\phi\theta} \tag{2.6c}$$

$$M_\phi = \left(\frac{\hat{M}_\phi R}{D}\right) = \chi_\phi + \nu\chi_\theta + M^T \tag{2.6d}$$

$$M_\theta = \left(\frac{\hat{M}_\theta R}{D}\right) = \chi_\theta + \nu\chi_\phi + M^T \tag{2.6e}$$

$$M_{\phi\theta} = M_{\theta\phi} = \left[\frac{\hat{M}_{\phi\theta}R}{(1-\nu)D}\right] = \chi_{\phi\theta} \tag{2.6f}$$

$$Q_\phi = \left(\frac{\hat{Q}_\phi R^2}{D}\right) = \chi_{\phi,\phi} + \nu\chi_{\theta,\phi} + (1-\nu)\cot\phi\ (\chi_\phi - \chi_\theta) + \left[\frac{(1-\nu)}{\sin\phi}\right]\chi_{\phi\theta,\phi} + M^T_{,\phi} \tag{2.6g}$$

$$Q_\theta = \left(\frac{\hat{Q}_\theta R^2}{D}\right) = \chi_{\theta,\theta} + \nu\chi_{\phi,\theta} + 2(1-\nu)\cot\phi\ \chi_{\phi\theta} + (1-\nu)\chi_{\phi\theta,\phi} + M^T_{,\theta} \tag{2.6h}$$

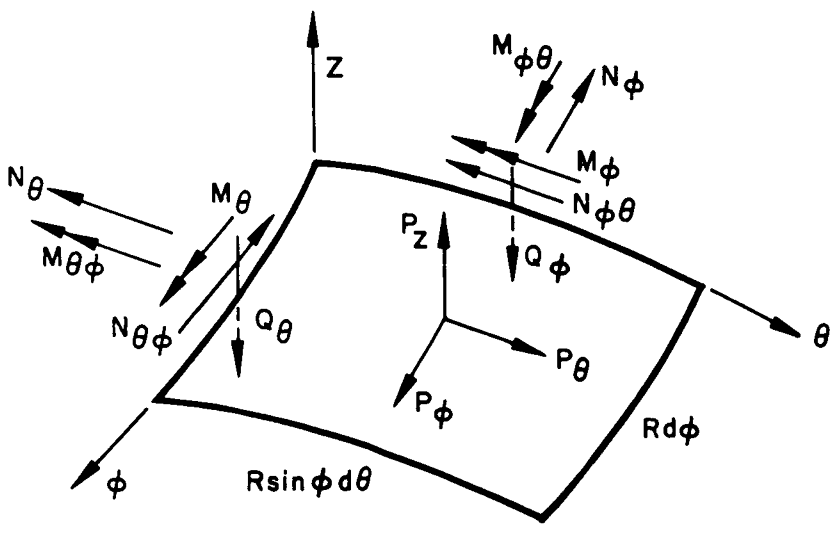


Fig. 5 Stress Resultants, Moments, and Loads

where

$$N^T = \left[\frac{\hat{N}^T(1-\nu^2)}{E\hat{h}}\right] = -(1+\nu)\frac{1}{\hat{h}}\int_{-h/2}^{h/2} \alpha T \, dz$$

$$M^T = \left(\frac{\hat{M}^T R}{D}\right) = -12(1+\nu)\frac{1}{\hat{h}^3}\int_{-h/2}^{h/2} \alpha T \, z \, dz$$

and T is temperature change relative to a zero thermal stress condition; α, the coefficient of thermal expansion; and $\kappa = h^2/12$.

2.1.4 Governing Differential Equations

The governing differential equations for a spherical shell in terms of displacement components u, v, and w are given by

$$a_1 u_{,\phi\phi} + a_2 u_{,\theta\theta} + a_3 u_{,\phi} + a_4 u + a_5 v_{,\phi\theta} + a_6 v_{,\theta}$$
$$+ a_7 w_{,\phi\phi\phi} + a_8 w_{,\phi\theta\theta} + a_9 w_{,\phi\phi} + a_{10} w_{,\theta\theta} + a_{11} w_{,\phi} = A \qquad (2.7a)$$

$$b_1 u_{,\phi\theta} + b_2 u_{,\theta} + b_3 v_{,\phi\phi} + b_4 v_{,\theta\theta} + b_5 v_{,\phi} + b_6 v$$
$$+ b_7 w_{,\phi\phi\theta} + b_8 w_{,\theta\theta\theta} + b_9 w_{,\phi\theta} + b_{10} w_{,\theta} = B \qquad (2.7b)$$

$$c_1 u_{,\phi\phi\phi} + c_2 u_{,\phi\theta\theta} + c_3 u_{,\phi\phi} + c_4 u_{,\theta\theta} + c_5 u_{,\phi} + c_6 u$$
$$+ c_7 v_{,\phi\phi\theta} + c_8 v_{,\theta\theta\theta} + c_9 v_{,\phi\theta} + c_{10} v_{,\theta}$$
$$+ c_{11} w_{,\phi\phi\phi\phi} + c_{12} w_{,\phi\phi\theta\theta} + c_{13} w_{,\theta\theta\theta\theta}$$
$$+ c_{14} w_{,\phi\phi\phi} + c_{15} w_{,\phi\theta\theta} + c_{16} w_{,\phi\phi} + c_{17} w_{,\theta\theta}$$
$$+ c_{18} w_{,\phi} + c_{19} w = C \qquad (2.7c)$$

where

$$a_1 = (1 + \kappa) \sin \phi$$

$$a_2 = (1 + 4\kappa) \frac{1 - \nu}{2 \sin \phi}$$

$$a_3 = (1 + \kappa) \cos \phi$$

$$a_4 = - \frac{\cos^2 \phi + \nu \sin^2 \phi}{\sin \varphi} (1 + \kappa)$$

$$a_5 = \frac{1 + \nu}{2} + (2 - \nu)\kappa$$

$$a_6 = - \frac{\cot \phi}{2} \left[3 - \nu + 2\kappa(3 - 2\nu)\right]$$

$$a_7 = - \kappa \sin \phi$$

$$a_8 = -(2 - \nu) \frac{\kappa}{\sin \phi}$$

$$a_9 = -\kappa \cos \phi$$

$$a_{10} = (3 - \nu) \frac{\kappa}{\sin \phi} \cot \phi$$

$$a_{11} = (1 + \nu) \sin \phi + \frac{\cos^2 \phi + \nu \sin^2 \phi}{\sin \phi} \kappa$$

$$b_1 = \frac{1 + \nu}{2} + (2 - \nu)\kappa$$

$$b_2 = \left[\frac{3 - \nu}{2} + (3 - 2\nu)\kappa\right] \cot \phi$$

$$b_3 = \frac{1 - \nu}{2} (1 + 4\kappa) \sin \phi$$

$$b_4 = \frac{1 + \kappa}{\sin \phi}$$

$$b_5 = \frac{1 - \nu}{2} (1 + 4\kappa) \cos \phi$$

$$b_6 = \frac{1 - \nu}{2} \left(\frac{\sin^2 \phi - \cos^2 \phi}{\sin \phi}\right) (1 + 4\kappa)$$

$$b_7 = -(2 - \nu)\kappa$$

$$b_8 = -\frac{\kappa}{\sin^2 \phi}$$

$$b_9 = -\kappa \cot \phi$$

$$b_{10} = (1 + \nu) - 2\kappa(1 - \nu)$$

$$c_1 = \sin \phi$$

$$c_2 = \frac{2 - \nu}{\sin \phi}$$

$$c_3 = 2 \cos \phi$$

$$c_4 = \frac{\cos \phi}{\sin^2 \phi}$$

$$c_5 = -\left(\frac{1 + \nu \sin^2 \phi}{\sin \phi} + \frac{1 + \nu}{\kappa} \sin \phi\right)$$

$$c_6 = \left(1 - \nu - \frac{1 + \nu}{\kappa} + \frac{1}{\sin^2 \phi}\right) \cos \phi$$

$$c_7 = 2 - \nu$$

$$c_8 = \frac{1}{\sin^2 \phi}$$

$$c_9 = -\cot \phi$$

$$c_{10} = \left[2(1 - \nu) - \frac{1 + \nu}{\kappa} + \frac{1}{\sin^2 \phi}\right]$$

$$c_{11} = -\sin \phi$$

$$c_{12} = -\frac{2}{\sin \phi}$$

$$c_{13} = -\frac{1}{\sin^3 \phi}$$

$$c_{14} = -2 \cos \phi$$

$$c_{15} = 2 \frac{\cos \phi}{\sin^2 \phi}$$

$$c_{16} = \frac{1 + \nu \sin^2 \phi}{\sin \phi}$$

$$c_{17} = -\frac{4 - (1 + \nu) \sin^2 \phi}{\sin^3 \phi}$$

$$c_{18} = -\left(1 - \nu + \frac{1}{\sin^2 \phi}\right) \cos \phi$$

$$c_{19} = -2 \frac{1 + \nu}{\kappa} \sin \phi$$

In general, the loading functions are

$$A = -\sin \phi \left[(1 - \nu^2) \frac{p_\phi R}{E\hat{h}} + N^T_{,\phi} + \kappa M^T_{,\phi}\right] \tag{2.8a}$$

$$B = -\left[(1 - \nu^2) p_\theta R \frac{\sin \phi}{E\hat{h}} + N^T_{,\theta} + \kappa M^T_{,\theta}\right] \tag{2.8b}$$

$$C = -\sin \phi \left[R^3 \frac{p_z}{D} - \frac{2N^T}{\kappa} + M^T_{,\phi\phi} + \cot M^T_{,\phi} + \left(\frac{1}{\sin^2 \phi}\right) M^T_{,\theta\theta}\right] \tag{2.8c}$$

As mentioned in Sec. 4, the digital computer program which has been prepared has two options for loading. Specialization of the loading functions for each of these options follows:

- Uniform pressure

$$A = B = 0$$

$$C = -\sin \phi \frac{R^2 p_z}{D} = -\sin \phi$$

This will yield solutions normalized by $R^3 p_z/D$. For a given pressure, modulus, and value of Poisson's ratio this quantity can be found. The values of the dimensional dependent variables, $\hat{u}$, $\hat{v}$, and $\hat{w}$, can be computed from the nondimensional u, v, and w, obtained from the computer solution as

$$\hat{u} = \left(\frac{R^4 p_z}{D}\right) u$$

$$\hat{v} = \left(\frac{R^4 p_z}{D}\right) v$$

$$\hat{w} = \left(\frac{R^4 p_z}{D}\right) w$$

- Linear thermal gradient through the thickness of the shell
  For this special case T is given by

$$T = T_1 + T_2 z$$

where

$$T_1 = \frac{1}{2}(T_e + T_i) - 2T_o$$

$$T_2 = \frac{(T_e - T_i)}{h}$$

and

T_e = temperature at external surface $\left(z = \frac{h}{2}\right)$

T_i = temperature at internal surface $\left(z = -\frac{h}{2}\right)$

T_o = reference temperature

Then in nondimensional form

$$N^T = -(1 + \nu)\, \alpha T_1$$

$$M^T = -(1 + \nu)\, \alpha T_2$$

The loading functions in nondimensional form become

$$A = B = 0$$

$$C = -2 \sin \varphi \frac{(1 + \nu)\, \alpha T_1}{\kappa}$$

Dimensional displacements can be computed from the nondimensional solutions for u , v , and w through the relationships

$$\hat{u} = uR$$

$$\hat{v} = vR$$

$$\hat{w} = wR$$

2.2 BOUNDARY CONDITIONS

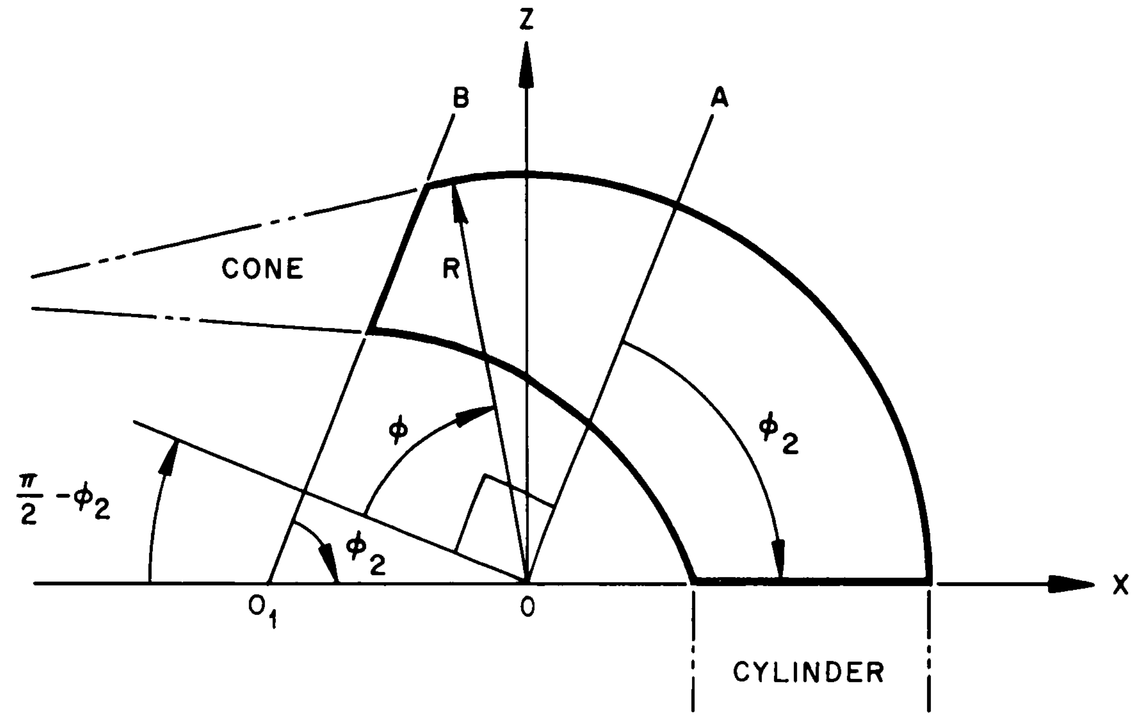
It was pointed out in Sec. 2.1 that the coordinates can be oriented so as to obtain a convenient description of the boundary curve. By such a description it is implied that the boundary is parallel or nearly parallel to coordinate lines. Two orientations of the orthogonal coordinates ϕ and θ are shown in Fig. 6. The coordinates in the two orientations are related to the rectangular coordinate system as follows:

Orientation 1

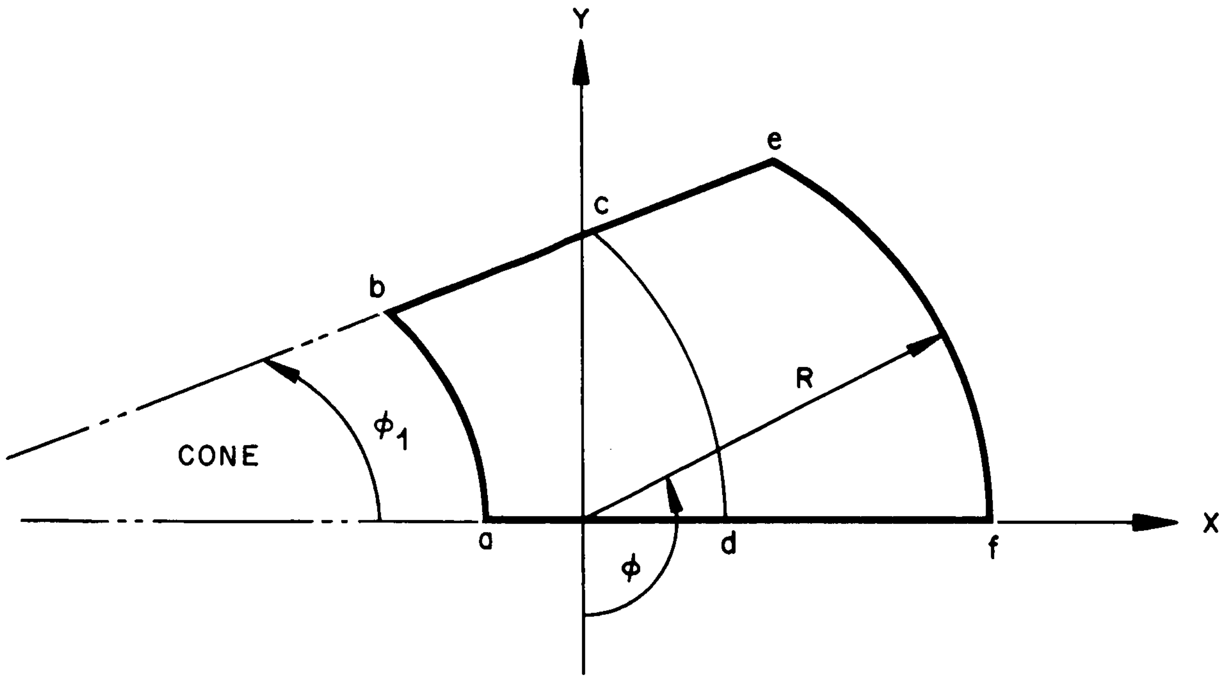
$$x = R(\sin \phi \cos \phi_2 \cos \theta - \cos \phi \sin \phi_2) \tag{2.9a}$$

$$y = R \sin \phi \sin \theta \tag{2.9b}$$

$$z = R(\cos \phi \cos \phi_2 + \sin \phi \cos \theta \sin \phi_2) \tag{2.9c}$$



Orientation 1 (Side View)



Orientation 2 (Top View)

Fig. 6 Orientations of Coordinate ϕ

Orientation 2

$$x = R \sin \phi \cos \theta \quad (2.10a)$$

$$y = -R \cos \phi \quad (2.10b)$$

$$z = R \sin \phi \sin \theta \quad (2.10c)$$

To use these orientations, consider the sphere cut as shown in Fig. 6 by the plane OA which is parallel to plane O_1B. That part of the sphere which is between the cone and plane OA is described by Orientation 1; the remaining portion, by Orientation 2. Thus, the sphere is divided into two parts each of which has two boundaries parallel to the curvilinear coordinates. The boundary curve and boundary conditions of Orientation 1 are given as shown in Fig. 7.

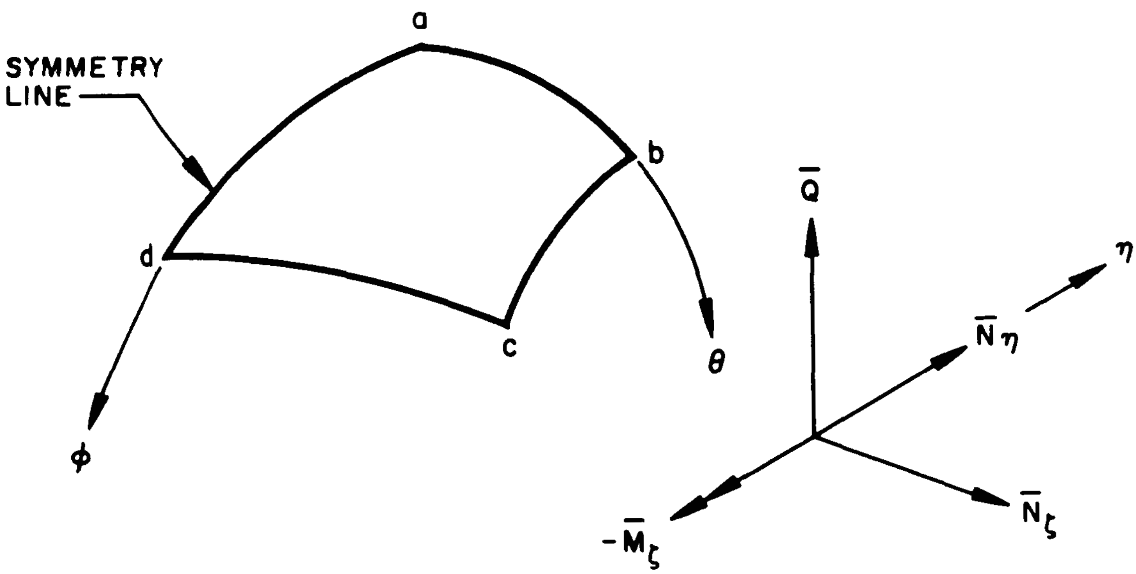


Fig. 7 Boundary Curve and Forces for Orientation 1

The boundary forces along the edges of the shell are given by the equations:

along $\overline{ab}$

$$\bar{N}_\eta = N_{\phi\theta} + 2\kappa M_{\phi\theta}$$

$$\bar{N}_\zeta = N_\phi$$

$$\bar{Q} = -\left[Q_\phi + \frac{(1 - \nu)}{\sin\phi} M_{\phi\theta,\theta}\right]$$

$$\bar{M}_\zeta = M_\phi$$

along $\overline{cd}$

$$\bar{N}_\eta = N_{\phi\theta} + 2\kappa M_{\phi\theta}$$

$$\bar{N}_\zeta = N_\phi$$

$$\bar{Q} = Q_\phi + \frac{(1 - \nu)}{\sin\phi} M_{\phi\theta,\theta}$$

$$\bar{M}_\zeta = M_\phi$$

along $\overline{bc}$

Since the curve $\overline{bc}$ is not parallel to a coordinate line the boundary forces are given by the general expressions:

$$\hat{\bar{N}}_\eta = \hat{N}_\eta + \frac{1}{R}\hat{M}_{\zeta\eta}$$

$$\hat{\bar{N}}_\zeta = \hat{N}_\zeta$$

$$\hat{\bar{Q}} = \hat{Q}_3 + \frac{1}{A_\eta} \frac{\partial \hat{M}_{\zeta\eta}}{\partial \eta}$$

$$\hat{\bar{M}}_\zeta = \hat{M}_\zeta$$

where

$$\hat{N}_\zeta = \cos^2 \lambda \, \hat{N}_\theta + \sin^2 \lambda \, \hat{N}_\phi + \sin 2\lambda \, \hat{N}_{\phi\theta}$$

$$\hat{N}_\eta = \frac{1}{2} \sin 2\lambda \, (\hat{N}_\theta - \hat{N}_\phi) + (\sin^2 \lambda - \cos^2 \lambda) \, \hat{N}_{\phi\theta}$$

$$\hat{Q}_3 = \sin \lambda \, \hat{Q}_\phi + \cos \lambda \, \hat{Q}_\theta$$

$$\hat{M}_\zeta = \cos^2 \lambda \, \hat{M}_\theta + \sin^2 \lambda \, \hat{M}_\phi + \sin 2\lambda \, \hat{M}_{\phi\theta}$$

$$\hat{M}_{\zeta\eta} = \frac{1}{2} \sin 2\lambda \, (M_\theta - M_\phi) + (\sin^2 \lambda - \cos^2 \lambda) \, \hat{M}_{\phi\theta} .$$

The direction cosine must be found from the following intersection relations:

$$\cos \lambda = \pm \frac{1}{[f^2 \sin^2 \phi + 1]^{1/2}}$$

where λ is the angle between the boundary curve and the ϕ-axis and

$$f = \frac{\tan \phi_1}{\sin^2 \phi} \left[\frac{-(R_1/R - 1) \cos \phi + \sin \phi_2}{\cos \theta + \tan \phi_1 \cos \phi_2 \sin \theta} \right]$$

The relation between θ and ϕ is found by the relation

$$\sin\theta - \tan\phi_1 \cos\phi_2 \cos\theta = \frac{\tan\phi_1}{\sin\phi}\left[\left(\frac{R_1}{R} - 1\right) - \sin\phi_2 \cos\phi\right].$$

For the spherical segment to have fixed edges, the displacement components are all zero. Hence, the required boundary conditions are as follows:

$$\overline{ab} \qquad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \phi} \equiv 0$$

$$\overline{bc} \qquad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \zeta} \equiv 0$$

$$\overline{cd} \qquad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \phi} \equiv 0$$

The boundary curve and boundary condition of Orientation 2 are given as shown in Fig. 8.

The boundary forces along the edges of the shell are given by the equations:

along $\overline{dc}$

$$\bar{N}_\eta = -N_{\theta\phi} - 2\kappa M_{\phi\theta}$$

$$\bar{N}_\zeta = N_\theta$$

$$\overline{Q} = Q_\theta + (1 - \nu) M_{\phi\theta,\phi}$$

$$\overline{M}_\zeta = M_\theta$$

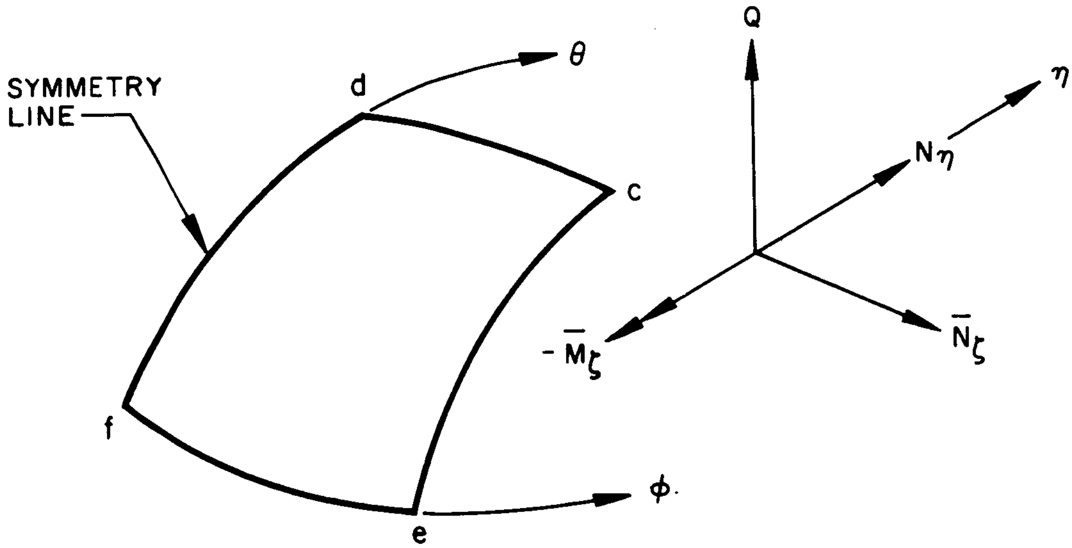


Fig. 8 Boundary Curve and Forces for Orientation 2

along $\overline{ef}$

$$\bar{N}_{\eta} = -N_{\theta\phi} - 2\kappa M_{\phi\theta}$$
$$\bar{N}_{\zeta} = N_{\theta}$$
$$\bar{Q} = -[Q + (1 - \nu)M_{\phi\theta,\phi}]$$
$$\bar{M}_{\zeta} = M_{\theta}$$

along $\overline{ce}$

The curve $\overline{ce}$ is not parallel to a coordinate lines as was the case for line $\overline{bc}$ for Orientation 1. Thus, the boundary forces are given by the general expressions:

$$\hat{\bar{N}}_{\eta} = \hat{N}_{\eta} + \frac{1}{R}\hat{M}_{\zeta\eta}$$
$$\hat{\bar{N}}_{\zeta} = \hat{N}_{\zeta}$$
$$\hat{\bar{Q}} = \hat{Q}_3 + \frac{1}{A_{\eta}}\frac{\partial\hat{M}_{\zeta\eta}}{\partial\eta}$$
$$\hat{\bar{M}}_{\zeta} = \hat{M}_{\zeta}$$

The quantities $\hat{N}_\eta$, $\hat{N}_\xi$, $\hat{Q}_3$, $\hat{M}_\xi$, $\hat{M}_{\xi\eta}$ can be found by the equations given for Orientation 1, once $\cos \lambda$ is known. For the curve $\overline{ce}$, the relation between θ and ϕ is

$$\cos \theta = - \frac{[\cos \phi + \tan \phi_1 (R_1/R - 1)]}{\sin \phi \tan \phi_1}$$

The direction cosine is given by

$$\cos \lambda$$

$$= \pm \frac{\left\{\tan^2 \phi_1 \sin^2 \phi - \left[\cos \phi + \tan \phi_1 (R_1/R - 1)\right]^2\right\}^{1/2}}{\left\{\left[1 + \tan \phi_1 (R_1/R - 1) \cos \phi\right]^2 + \tan^2 \phi_1 \sin^2 \phi - \left[\cos \phi + \tan \phi_1 (R_1/R - 1)\right]^2\right\}^{1/2}}$$

For the spherical segment, $\overline{dcef}$, the boundary conditions for a fixed edge are as follows:

$$\overline{dc} \qquad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \theta} \equiv 0$$

$$\overline{bc} \qquad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \xi} \equiv 0$$

$$\overline{cd} \qquad u \equiv v \equiv w \equiv \frac{\partial w}{\partial \theta} \equiv 0$$

2.3 STRESS IN SKIN

Once the stress resultant and couples are known, the corresponding maximum and minimum stress of an isotropic shell can be computed by the relations:

$$\sigma_\phi = \frac{1}{\hat{h}} \hat{N}_\phi \pm \frac{6}{\hat{h}^2} \hat{M}_\phi \qquad (2.11a)$$

$$\sigma_\theta = \frac{1}{\hat{h}} \hat{N}_\theta \pm \frac{6}{\hat{h}^2} \hat{M}_\theta \qquad (2.11b)$$

This development is based on the assumption of a linear stress variation through the thickness given by

$$\sigma_i = \bar{\sigma}_i + z\sigma_i^b$$

where $\bar{\sigma}_i$ is a membrane stress and $z\sigma_i^b$ in the stress due to bending.

Section 3
NUMERICAL ANALYSIS

The finite-difference method is used to solve the governing equations of a spherical shell segment with fixed edges. The scheme in this numerical method is to replace the continuous problem of a continuous coordinate system by one defined at a finite number of coordinate points. To accomplish this discretization, the continuous two dimensional (ϕ , θ) domain of the spherical shell is covered by a uniform rectangular net as shown in Fig. 9. Lattice points of this net which are within the domain $\underset{\sim}{D}$

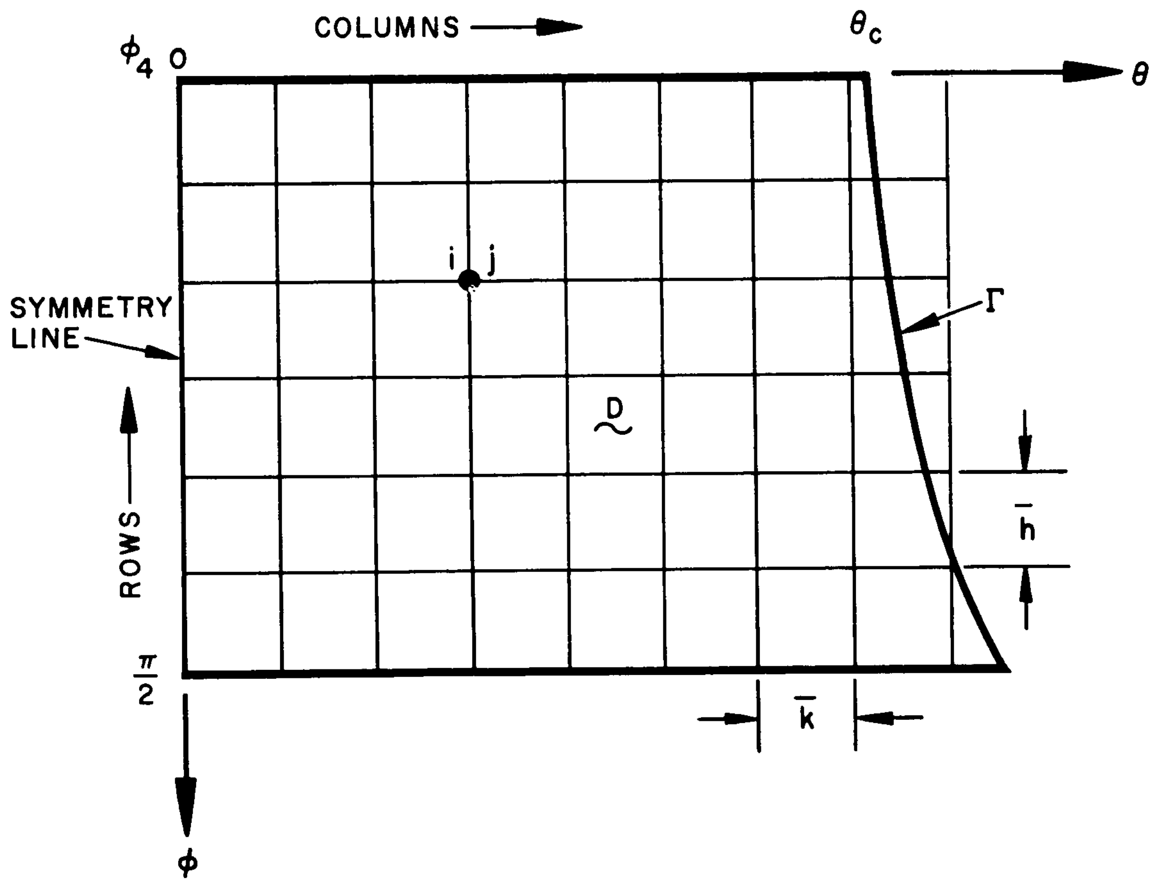


Fig. 9 Domain and Boundary of Spherical Shell Segment

are called mesh points, and lattice points on the boundary curve Γ are called boundary points. At these lattice points the dependent variables (u, v, w) of the governing differential equations are replaced by the discrete values of u_i^j, v_i^j, w_i^j. The subscript i of u_i^j denotes the row number and corresponds to the ϕ-coordinate while the superscript j denotes the column number and corresponds to the θ-coordinate. In general, the boundary curve does not coincide with the net as seen in Fig. 9. For the present numerical analysis, it is desirable to have the boundary curve coincide with the net so as to avoid computational complications. With the orthogonal coordinates ϕ, θ, it is not possible to have all the coordinate lines coincide exactly with the boundary. However, the coordinates can be orientated in such a manner that at least two boundary curves are parallel to coordinate lines. Two orientations are given in Sec. 2.2 which accomplish this objective. The domain shown in Fig. 9 corresponds to Orientation 1 which indicates the degree to which the actual boundary curve deviates from the rectangular net.

The difference equations which are a set of algebraic relations representing the governing equations and boundary conditions are formed by first approximating the derivatives at a given point by a function of the variable at neighboring points. These functions replace the derivatives of the governing equations. Thus, at each mesh point three algebraic equations can be written in terms of neighboring points. When the boundary conditions are accounted for in these equations the resulting set of simultaneous algebraic equations

$$\underset{\sim}{A}\underset{\sim}{X} = \underset{\sim}{B}$$

replaces the continuous problem. The solution of this set of algebraic equations can be accomplished by methods described in Vol. I.

3.1 APPROXIMATION OF DERIVATIVES

The derivatives of u, v, w are expressed in terms of their values at neighboring mesh points to transform the governing equations to difference form. These derivatives are determined by a Taylor series approximation* for a rectangular net and are given by the following equations:

$$f_{,\phi} = 1/2\bar{h}\left(f_1^o - f_{-1}^o\right) \tag{3.1a}$$

$$f_{,\phi\phi} = 1/\bar{h}^2\left(f_1^o - 2f_o^o + f_{-1}^o\right) \tag{3.1b}$$

$$f_{,\phi\phi\phi} = 1/2\bar{h}^3\left(f_2^o - 2f_1^o + 2f_{-1}^o - f_{-2}^o\right) \tag{3.1c}$$

$$f_{,\phi\phi\phi\phi} = 1/\bar{h}^4\left(f_2^o - 4f_1^o + 6f_o^o - 4f_{-1}^o + f_{-2}^o\right) \tag{3.1d}$$

$$f_{,\theta} = 1/2\bar{k}\left(f_o^1 - f_o^{-1}\right) \tag{3.1e}$$

$$f_{,\theta\theta} = 1/\bar{k}^2\left(f_o^1 - 2f_o^o + f_o^{-1}\right) \tag{3.1f}$$

$$f_{,\theta\theta\theta} = 1/2\bar{k}^3\left(f_o^2 - 2f_o^1 + 2f_o^{-1} - f_o^{-2}\right) \tag{3.1g}$$

$$f_{,\theta\theta\theta\theta} = 1/\bar{k}^4\left(f_o^2 - 4f_o^1 + 6f_o^o - 4f_o^{-1} + f_o^{-2}\right) \tag{3.1h}$$

$$f_{,\phi\theta} = 1/4\bar{h}\bar{k}\left(f_1^1 - f_{-1}^1 - f_1^{-1} + f_{-1}^{-1}\right) \tag{3.1i}$$

$$f_{,\phi\phi\theta} = 1/2\bar{h}^2\bar{k}\left(-2f_o^1 + 2f_o^{-1} + f_1^1 + f_{-1}^1 - f_1^{-1} - f_{-1}^{-1}\right) \tag{3.1j}$$

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*"Investigation of Juncture Stress Fields in Multicellular Shell Structures," by E. Y. W. Tsui, F. A. Brogan, J. M. Massard, P. Stern, and C. E. Stuhlman, Technical Report M-03-63-1, Lockheed Missiles & Space Company, Sunnyvale, Calif., Feb 1964 – NASA CR-61050.

$$f_{,\phi\theta\theta} = 1/2\bar{h}\bar{k}^{2}\left(-2f_{1}^{o} + 2f_{-1}^{o} + f_{1}^{1} + f_{1}^{-1} - f_{-1}^{1} - f_{-1}^{-1}\right) \tag{3.1k}$$

$$f_{,\phi\phi\theta\theta} = 1/\bar{h}^{2}k^{-2}\left(-2f_{1}^{o} - 2f_{-1}^{o} - 2f_{o}^{1} - 2f_{o}^{-1} + f_{1}^{1} + f_{-1}^{1} + f_{1}^{-1} + f_{-1}^{-1} + 4f_{o}^{o}\right) \tag{3.1l}$$

Lower order approximations to be used as noted

$$u_{,\phi\phi\phi} = 1/\bar{h}^{3}\left(u_{2}^{o} - 3u_{1}^{o} + 3u_{o}^{o} - u_{-1}^{o}\right) \tag{3.1m}$$

$$u_{,\phi\phi\phi} = 1/\bar{h}^{3}\left(u_{1}^{o} - 3u_{o}^{o} + 3u_{-1}^{o} - u_{-2}^{o}\right) \tag{3.1n}$$

$$v_{,\theta\theta\theta} = 1/\bar{k}^{3}\left(v_{o}^{1} - 3v_{o}^{o} + 3v_{o}^{-1} - v_{o}^{-2}\right) \tag{3.1o}$$

3.2 DIFFERENCE EQUATIONS

The formation of the difference equations is effected in a straightforward manner by substituting the appropriate expressions of Eqs. (3.1) into the governing equation [Eqs. (2.7)]. Only when the equations are written one row or column from the boundary, the low-order third derivatives of u with respect to ϕ [Eqs. (3.1m and n)] or the third derivative of v with respect to θ [Eq. (3.1o)] are used to obtain a sufficient number of unknowns for the given number of equations. With these substitutions the three governing equations in difference form at a point 0, 0 are as follows:

$$\begin{aligned} A_1u_1^o + A_2u_{-1}^o + A_3\left(u_o^1 + u_o^{-1}\right) + A_4u_o^o + A_5\left(v_1^1 - v_1^{-1} - v_{-1}^1 + v_{-1}^{-1}\right) \\ + A_6\left(v_o^1 - v_o^{-1}\right) + A_7\left(w_2^o - w_{-2}^o\right) + A_8w_1^o + A_9w_{-1}^o + A_{10}\left(w_o^1 + w_o^{-1}\right) \\ + A_{11}\left(w_1^1 + w_1^{-1} - w_{-1}^1 - w_{-1}^{-1}\right) + A_{12}w_o^o = A_o^o \end{aligned} \tag{3.2a}$$

$$B_1\left(u_1^1 - u_{-1}^1 - u_1^{-1} + u_{-1}^{-1}\right) + B_2\left(u_o^1 - u_o^{-1}\right) + B_3 v_1^o + B_4 v_{-1}^o + B_5\left(v_o^1 + v_o^{-1}\right)$$

$$+ B_6 v_o^o + B_7\left(w_o^1 - w_o^{-1}\right) + B_8\left(w_1^1 - w_1^{-1}\right) + B_9\left(w_{-1}^1 - w_{-1}^{-1}\right) + B_{10}\left(w_o^2 - w_o^{-2}\right) = B_o^o \quad (3.2b)$$

$$C_1\left(u_2^o - u_{-2}^o\right) + C_2 u_1^o + C_3 u_{-1}^o + C_4\left(-u_o^1 - u_o^{-1}\right) + C_5\left(u_1^1 - u_{-1}^1 + u_1^{-1} - u_{-1}^{-1}\right)$$

$$+ C_6 u_o^o + C_7\left(v_o^1 - v_o^{-1}\right) + C_8\left(v_1^1 - v_1^{-1}\right) + C_9\left(v_{-1}^1 - v_{-1}^{-1}\right) + C_{10}\left(v_o^2 - v_o^{-2}\right)$$

$$+ C_{11} w_2^o + C_{12} w_{-2}^o + C_{13}\left(w_o^2 + w_o^{-2}\right) + C_{14} w_1^o + C_{15} w_{-1}^o + C_{16}\left(w_o^1 + w_o^{-1}\right)$$

$$+ C_{17}\left(w_1^1 + w_1^{-1}\right) + C_{18}\left(w_{-1}^1 + w_{-1}^{-1}\right) + C_{19} w_o^o = C_o^o \quad (3.2c)$$

where

$$A_1 = \frac{a_1}{\bar{h}^2} + \frac{a_3}{2\bar{h}}$$

$$A_2 = \frac{a_1}{\bar{h}^2} - \frac{a_3}{2\bar{h}}$$

$$A_3 = \frac{a_2}{\bar{k}^2}$$

$$A_4 = a_4 - (A_1 + A_2) - 2A_3$$

$$A_5 = \frac{a_5}{4\bar{h}\bar{k}}$$

$$A_6 = \frac{a_6}{2\bar{k}}$$

$$A_7 = \frac{a_7}{2\bar{h}^3}$$

$$A_8 = -2A_7 - 2A_{11} + \frac{a_9}{\bar{h}^2} + \frac{a_{11}}{2\bar{h}}$$

$$A_9 = 2A_7 + 2A_{11} + \frac{a_9}{\bar{h}^2} - \frac{a_{11}}{2\bar{h}}$$

$$A_{10} = \frac{a_{10}}{\bar{k}^2}$$

$$A_{11} = \frac{a_8}{2\bar{h}\bar{k}^2}$$

$$A_{12} = -\frac{2a_9}{\bar{h}^2} - 2A_{10}$$

$$A_o^o = A$$

$$B_1 = \frac{b_1}{4\bar{h}\bar{k}}$$

$$B_2 = \frac{b_2}{2\bar{k}}$$

$$B_3 = \frac{b_3}{\bar{h}^2} + \frac{b_5}{2\bar{h}}$$

$$B_4 = \frac{b_3}{\bar{h}^2} - \frac{b_5}{2\bar{h}}$$

$$B_5 = \frac{b_4}{\bar{k}^2}$$

$$B_6 = -(B_3 + B_4) - 2B_5 + b_6$$

$$B_7 = \left(-\frac{b_7}{2\bar{h}^2\bar{k}} + \frac{b_{10}}{2\bar{k}} - \frac{b_8}{\bar{k}^3}\right)$$

$$B_8 = \left(\frac{b_7}{2\bar{h}^2\bar{k}} + \frac{b_9}{4\bar{h}\bar{k}}\right)$$

$$B_9 = \left(\frac{b_7}{2\bar{h}^2\bar{k}} - \frac{b_9}{4\bar{h}\bar{k}}\right)$$

$$B_{10} = \frac{b_8}{2\bar{k}^3}$$

$$B_o^o = B$$

$$C_1 = \frac{c_1}{2\bar{h}^3}$$

$$C_2 = -2C_1 - 2C_5 + \frac{c_3}{\bar{h}^2} + \frac{c_5}{2\bar{h}}$$

$$C_3 = \frac{c_1}{\bar{h}^3} + \frac{c_2}{\bar{h}\bar{k}^2} + \frac{c_3}{\bar{h}^2} - \frac{c_5}{2\bar{h}}$$

$$C_4 = \frac{c_4}{\bar{k}^2}$$

$$C_5 = \frac{c_2}{2\bar{h}\bar{k}^2}$$

$$C_6 = -2\frac{c_3}{\bar{h}^2} - 2\frac{c_4}{\bar{k}^2} + c_6$$

$$C_7 = -\frac{c_7}{\bar{h}^2\bar{k}} - \frac{c_8}{\bar{k}^3} + \frac{c_{10}}{2\bar{k}}$$

$$C_8 = \frac{c_7}{2\bar{h}^2\bar{k}} + \frac{c_9}{4\bar{h}\bar{k}}$$

$$C_9 = \frac{c_7}{2\bar{h}^2\bar{k}} - \frac{c_9}{4\bar{h}\bar{k}}$$

$$C_{10} = \frac{c_8}{2\bar{k}^3}$$

$$C_{11} = \frac{c_{11}}{\bar{h}^4} + \frac{c_{14}}{2\bar{h}^3}$$

$$C_{12} = \frac{c_{11}}{\bar{h}^4} - \frac{c_{14}}{2\bar{h}^3}$$

$$C_{13} = \frac{c_{13}}{\bar{k}^4}$$

$$C_{14} = -4\frac{c_{11}}{\bar{h}^4} - 2\frac{c_{12}}{\bar{h}^2\bar{k}^2} - \frac{c_{14}}{\bar{h}^3} - \frac{c_{15}}{\bar{h}\bar{k}^2} + \frac{c_{16}}{\bar{h}^2} + \frac{c_{18}}{2\bar{h}}$$

$$C_{15} = -4\frac{c_{11}}{\bar{h}^4} - 2\frac{c_{12}}{\bar{h}^2\bar{k}^2} + \frac{c_{14}}{\bar{h}^3} + \frac{c_{15}}{\bar{h}\bar{k}^2} + \frac{c_{16}}{\bar{h}^2} - \frac{c_{18}}{2\bar{h}}$$

$$C_{16} = -2\frac{c_{12}}{\bar{h}^2\bar{k}^2} - 4\frac{c_{13}}{\bar{k}^4} + \frac{c_{17}}{\bar{k}^2}$$

$$C_{17} = \frac{c_{12}}{\bar{h}^2\bar{k}^2} + \frac{c_{15}}{2\bar{h}\bar{k}^2}$$

$$C_{18} = \frac{c_{12}}{\bar{h}^2\bar{k}^2} - \frac{c_{15}}{2\bar{h}\bar{k}^2}$$

$$C_{19} = 6\frac{c_{11}}{\bar{h}^4} + 4\frac{c_{12}}{\bar{h}^2\bar{k}^2} + 6\frac{c_{13}}{\bar{k}^4} - 2\frac{c_{16}}{\bar{h}^2} - 2\frac{c_{17}}{\bar{k}^2} + c_{19}$$

$$C_o^o = C$$

The complete set of difference equations are obtained by writing these equations at each mesh point. Along lines of symmetry only two equations are necessary since one of the variables will be zero. After incorporation of fixed-edge boundary conditions, a sufficient number of equations for unknowns yields a set of simultaneous algebraic equations which are written in matrix form as

$$\underset{\sim}{A}\underset{\sim}{X} = \underset{\sim}{B}$$

Unless care is exercised in ordering the equations and unknowns, the square matrix $\underset{\sim}{A}$ can be full. From the aspect of solving a large number of equations (Vol. I), the ordering is important. To establish an insight into the idea of the ordering employed, it is noticed from the difference expressions [Eqs. (3. 1)] that the highest derivatives are in terms of at most two rows "above;" two rows "below;" two columns to the "left," and two columns to the "right" of a given mesh point. If all the equations for a given column were written and stored in submatrix form, the unknowns would involve two columns to the "right" and "left." Thus, any column would involve, at most, five submatrices. The matrix $\underset{\sim}{A}$ is accordingly partitioned in the manner shown below, where m is the number of columns in the finite-difference net.

$$\underset{\sim}{A} = \begin{bmatrix} E_1 F_1 G_1 \cdots & & 0 \\ D_2 E_2 F_2 G_2 & & \\ C_3 D_3 E_3 F_3 G_3 0 & & \\ \vdots & & \\ & & G_{n-2} \\ & & F_{m-1} \\ & & C_m D_m E_m \end{bmatrix}$$

This matrix $\underset{\sim}{A}$ is obtained by writing Eqs. (3. 1) in $\underset{\sim}{D}$ and not on the boundary Γ. The boundary and symmetry conditions have been used to eliminate certain equations. Fixed-edge boundary conditions are well-suited for this formulation, since they do not require complex algebraic expressions. Specifically, if Eqs. (3. 1) are written one column from the boundary, then the submatrix F_m is zero $(u = v = w = 0)$

and the submatrix G_m contains only w terms which are reflected into E_m due to the boundary condition. Along a symmetry line, all terms are either reflected with the same or opposite sign. This fact accounts for the missing C_1 and D_1 matrices. Similar alterations are made in each matrix to account for boundary and symmetry conditions.

Because of the boundary behavior of shells it is desirable to incorporate a means of decreasing the mesh spacing in order to reveal the boundary solution with greater detail and accuracy. A rather simple method called grading which does not destroy the form of matrix $\underset{\sim}{A}$ is incorporated in the numerical solution. An explanation of grading was given in Vol. II, Sec. 3.3.

Section 4
DIGITAL PROGRAM

4.1 GENERAL DESCRIPTION

The present program provides solutions for fixed-edge spherical shell segments under loads and changes of temperature. The method of solution consists basically in obtaining the displacement components u, v, and w at various discrete stations of the structure by finite-difference approximation (see Secs. 2 and 3). The corresponding strains and stresses may then be computed.

The program is designed to compute the fixed-edge forces due to intermediate loads or thermal graident. However, displacements, strains, and stresses in the loaded region are also evaluated simultaneously. The following program options are available:

- Finite-difference mesh
  - (a) Uniform spacing
  - (b) Graded spacing in the ϕ-direction
  - (c) Symmetry in the ϕ-direction
- Loading conditions
  - (a) Uniform normal pressure
  - (b) Linear temperature gradient through the skin thickness

There are no restrictions on the geometrical dimensions of panels. However, the accuracy with which the basic differential equations are approximated may vary for different configurations of the shell.

The finite-difference mesh network is specified completely by prescribing the number of rows and columns exclusive of the boundaries, together with the grading options which have been chosen. Rows in the finite-difference mesh are parallel to the

θ-direction, and columns are parallel to the ϕ-direction. The number of rows may vary from 4 to 24 and the number of columns from 4 to 80. Thus, a maximum of 5760 unknowns can be solved. Greater accuracy near the boundaries can often be obtained by selective grading. By this means, it is possible to use a mesh spacing at the boundary as little as 1/32 of that at the middle portion of the panel.

There are certain restrictions on the use of the grading option. When such an option is used, a separate input card is required to specify a mesh spacing exponent MM(J) for each row J. The finite-difference equations are written along Row J, then the mesh spacing XH/2**MM(J) is used. This distance must be the least of the two distances from Row J to the row above and the row below. XH is the basic input mesh spacing along the ϕ-direction. For any Row J. MM(J) and MM(J + 1) must not differ by more than 1. Also, three consecutive rows cannot have three distinct exponents. MM(J) may vary from 0 to 5.

The description of symbols and input data are shown in Tables 1 and 2; **Fig.** 10 shows the flow diagram of this program.

Table 1

DESCRIPTION OF SYMBOLS

Symbol		Description
RECORD		Hollerith information describing problem
IϕPT1	0	Uniform mesh spacing
	1	Graded mesh spacing in ϕ-direction
IϕPT2	0	Symmetry in the ϕ-direction
	1	Row 1 is symmetry line
	2	Row 2 is adjacent to boundary
IϕPT3	0	Omit shell strains
	1	Print shell strains
IϕPT4	0	Uniform normal pressure
	1	Linear temperature gradient through the skin thickness

Table 1 (cont'd)

Symbol		Description
IφPT5	0	Not last case with plots
	1	Last case with plots
RφW		Number of rows in the finite-difference mesh
CφL		Number of columns in the finite-difference mesh
XH		Basic distance between rows in the mesh
XK		Basic distance between columns in the mesh
ZNU		Poisson's ratio
THC		Half angle of segment θ_c
PH1		Angle ϕ of upper boundary
FF		Ratio of angle of ϕ of lower boundary to ϕ of upper boundary
RH		Radius to thickness ratio, R/h
TE		External temperature
TI		Internal temperature
Tφ		Ambient temperature for zero stress
φC		Coefficient of thermal expansion
MM(J), J = 1, RφW		Grading mesh constants, mesh spacing used for difference equations on Row J is equal to XH/2.**MM(J)
MM(31)		Number of rows to be plotted
MM(32) MM(33) MM(34) MM(35)		Four row numbers for which plot output is desired (u, v, w, N_ϕ, M_ϕ, N_θ, M_θ)
CILBL(I, 1), I = 1, 6 CILBL(I, 2), I = 1, 6 CILBL(I, 3), I = 1, 6 CILBL(I, 4), I = 1, 6		Curve labels appearing on the plot output to identify the rows selected CILBL(I, 1) corresponds to MM(32); etc.

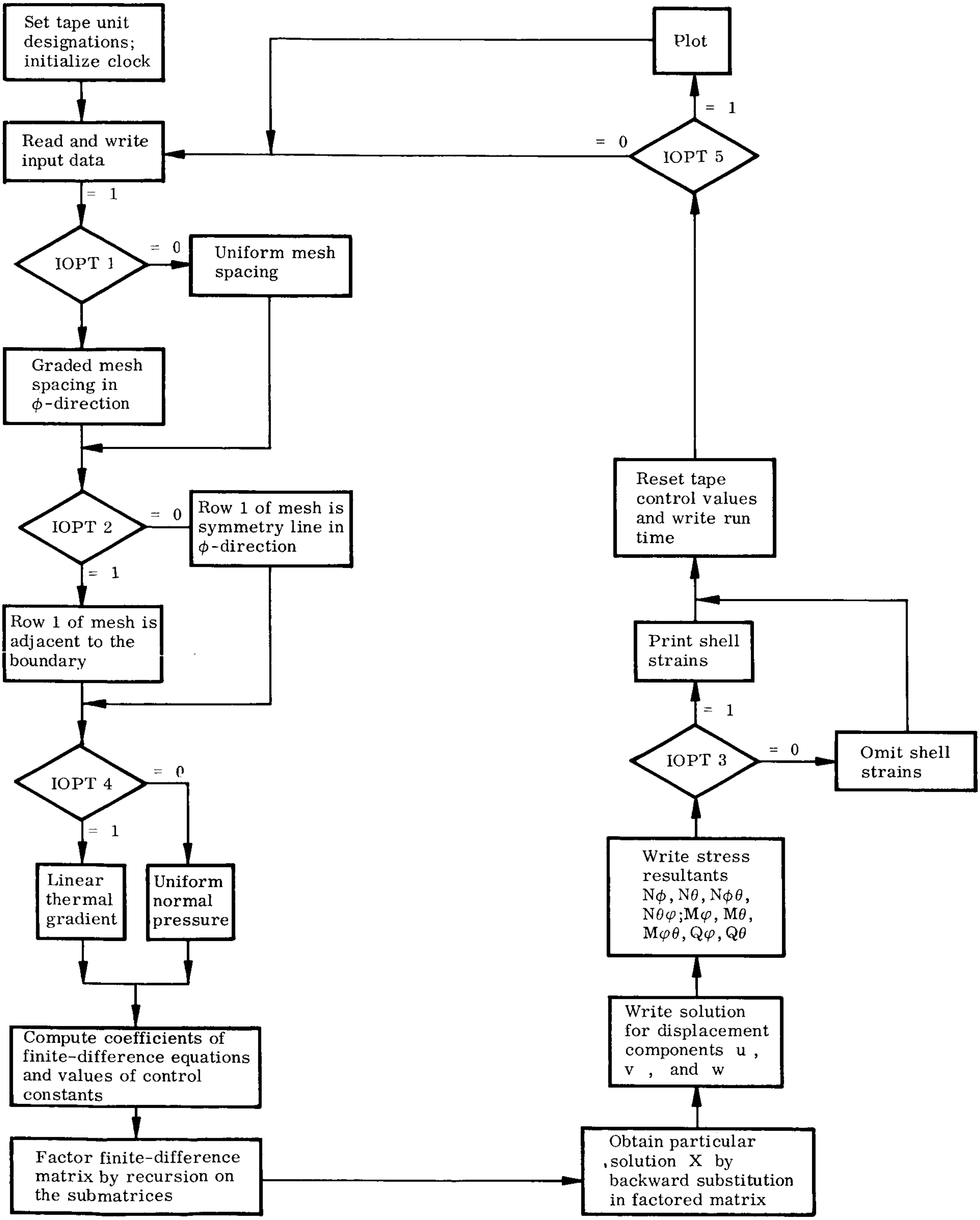


Fig. 10 Flow Chart

Table 2

INPUT DATA SEQUENCE AND FORMAT

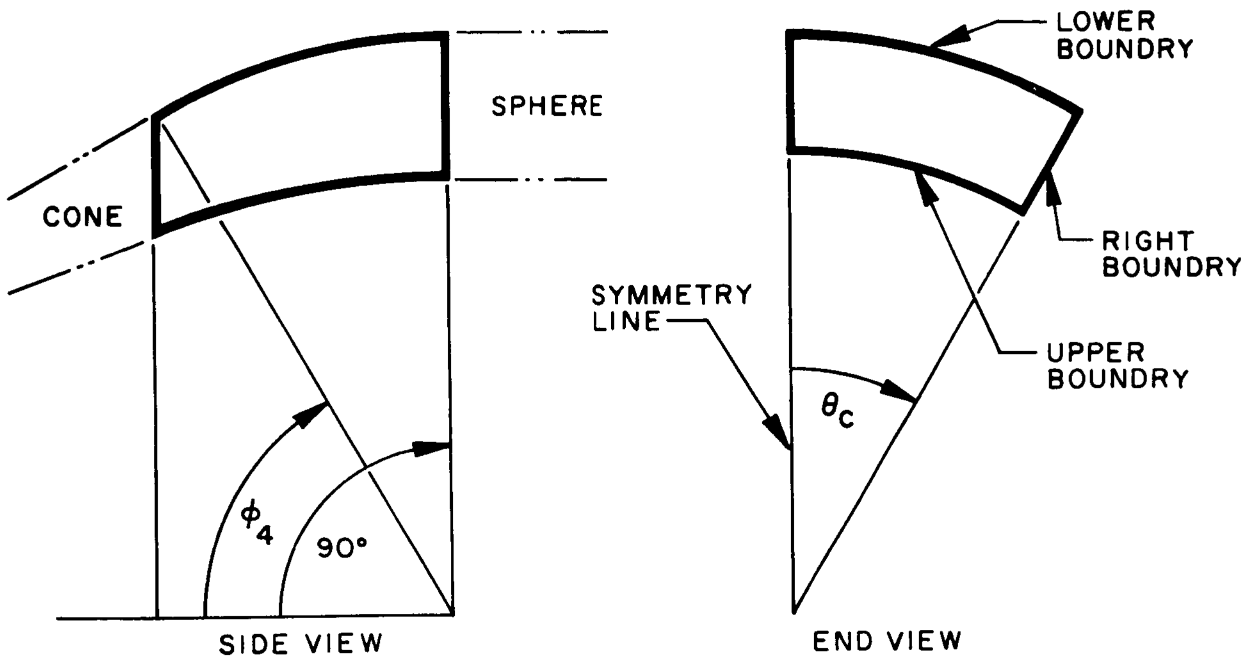
Card	FORTRAN Symbol	Format
1	RECORD	72H
2	IϕPT1, IϕPT2, IϕPT3, IϕPT4, IϕPT5	10I1
3	RϕW, CϕL, XH, XK	3E12.8
4	ZNU, THC, PH1, FF, RH	6E12.8
5[(a)]	MM(J), J = 1, RϕW	35I2
6[(b)]	TE, TI, Tϕ, ϕC	4E12.8
7	MM(J), J = 31, 35	5I2
8[(c)]	CILBL(I, 1), I = 1, 6	6A6
9[(c)]	CILBL(I, 2), I = 1, 6	6A6
10[(c)]	CILBL(I, 3), I = 1, 6	6A6
11[(c)]	CILBL(I, 4), I = 1, 6	6A6

(a) Omitted unless IϕPT1 = 1.
(b) Omitted unless IϕPT4 = 1.
(c) Omitted if MM(31) = 0.

4.2 NUMERICAL EXAMPLE

Analysis of the spherical shell segment shown in Fig. 11 will serve as an example to illustrate input data, format, and the type of information that can be obtained through use of the program described in this volume.

The example is for the loading option of uniform normal pressure (p_z = constant). Grading is used in the ϕ-coordinate so as to obtain a reasonable solution with the present restrictions of the computer program (24 rows, 80 columns). The actual



θ_C = THC = 0.61 RAD~~IUS~~

ϕ_4 = PHI = 1.0297 RAD~~IUS~~

$FF = \frac{\pi}{2} / 1.0297 = 1.5708$

$\frac{R}{h}$ = RH = 100

Fig. 11 Segmented Spherical Shell

mesh spacing which yields a solution of desired accuracy must be obtained by exploratory runs using different number of rows and columns. Such runs were made with the given geometry. It was found that 17 rows and 30 columns were required to obtain satisfactory results in both displacements and stress resultants. More accurate results can be obtained by use of an even finer mesh spacing.

Values of input quantities for the 17 by 30 case are given in Table 3 and a listing of the corresponding input data cards is presented in Table 4. For convenience, the ϕ-coordinate corresponding to the row number follows:

Table 3

INPUT VALUES FOR THE EXAMPLE

Symbol	Value	Symbol	Value
IφPT1	1.0	MM(8)	0
IφPT2	1.0	MM(9)	0
IφPT3	0	MM(10)	0
IφPT4	0	MM(11)	1.0
IφPT5	1.0	MM(12)	1.0
RφW	17.0	MM(13)	2.0
CφL	30.0	MM(14)	2.0
XH	0.067635	MM(15)	2.0
XK	0.02033	MM(16)	3.0
ZNU	0.3	MM(17)	3.0
THC	0.61	TE, TI, Tφ, φC	Not required
PH1	1.0297	MM(31)	4.0
FF	1.5255	MM(32)	5.0
RH	100.0	MM(33)	9.0
MM(1)	3.0	MM(34)	16.0
MM(2)	3.0	MM(35)	17.0
MM(3)	2.0	CILBL(I, 1)I = 1, 6	PHI = 1.503, Row 5
MM(4)	2.0	CILBL(I, 2)I = 1, 6	PHI = 1.300, Row 9
MM(5)	2.0	CILBL(I, 3)I = 1, 6	PHI = 1.038, Row 16
MM(6)	1.0	CILBL(I, 4)I = 1, 6	PHI = 1.029, Row 17
MM(7)	1.0		

Table 4

INPUT DATA IN REQUIRED FORMAT

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Columns 1–72	Columns 73–80
EXAMPLE SPHERICAL SEGMENT UNDER UNIFφRM NφRMAL PRESSURE	CARD 1
11001	CARD 2
17 +2 30 +2 067635 +0 02033 +0	CARD 3
3 +0 61 +0 10297 +1 15255 +1 1 +3	CARD 4
03030202020101000,000001010202020303	CARD 5
OMIT THIS CARD	CARD 6
0405091617	CARD 7
PHI = 1.503 , RφW 5	CARD 8
PHI = 1.300 , RφW 9	CARD 9
PHI = 1.038 , ROW 16	CARD 10
PHI = 1.029 , ROW 17	CARD 11

ϕ = 1.0297 – Row 18	ϕ = 1.3679 – Row 8
ϕ = 1.0381 – Row 17	ϕ = 1.4355 – Row 7
ϕ = 1.0466 – Row 16	ϕ = 1.4693 – Row 6
ϕ = 1.0635 – Row 15	ϕ = 1.5031 – Row 5
ϕ = 1.0804 – Row 14	ϕ = 1.5200 – Row 4
ϕ = 1.0973 – Row 13	ϕ = 1.5369 – Row 3
ϕ = 1.1311 – Row 12	ϕ = 1.5539 – Row 2
ϕ = 1.1650 – Row 11	ϕ = 1.5623 – Row 1
ϕ = 1.2326 – Row 10	ϕ = 1.5703 – Row 0
ϕ = 1.3002 – Row 9	

Results from the computer program are in the form of printed digital values and selected plots. Sample printed output given in Table 5 presents displacement components (u, v, w), stress resultants $(N_\phi, N_\theta, N_{\theta\phi}, N_{\phi\theta}, M_\phi, M_\theta, M_{\phi\theta}, Q_\phi, Q_\theta)$, and boundary stress resultants $(N_{tan}, N_{norm}, Q, M)$. (Note that these quantities are in nondimensional form as defined in Sec. 2.) Plotted output includes displacement components (u, v, w) and stress resultants $(N_\phi, N_\theta, M_\phi, M_\theta)$ along Rows 1, 2, 10, and 16 and boundary stress resultants $(N_{tan}, N_{norm}, Q, M)$ along the boundary curve. This plotted output is shown in Figs. 12a through o.

Table 5

EXAMPLE SPHERICAL SEGMENT UNDER UNIFORM NORMAL PRESSURE

SPHERE DISPLACEMENT COMPONENTS (U,V,W)

COL	ROW		U	V	W
19,	20		0.	0.	3.658652E-02
19,	19		-2.638945E-03	1.021954E-03	7.759879E-03
19,	18	BCUNDARY	0.	0.	0.
19,	17		2.602412E-03	-9.899542E-04	7.759879E-03
19,	16		5.086261E-03	-1.945970E-03	2.549251E-02
19,	15		9.652772E-03	-3.786246E-03	7.057005E-02
19,	14		1.323534E-02	-5.476061E-03	1.238788E-01
19,	13		1.572938E-02	-7.016443E-03	1.787364E-01
19,	12		1.853742E-02	-9.803262E-03	2.864289E-01
19,	11		1.769688E-02	-1.200326E-02	3.637405E-01
19,	10		1.115614E-02	-1.531577E-02	4.653016E-01
19,	9		-1.421190E-04	-1.615930E-02	4.937291E-01
19,	8		-1.144092E-02	-1.475764E-02	4.663140E-01
19,	7		-1.792110E-02	-1.120068E-02	3.641097E-01
19,	6		-1.868753E-02	-8.990277E-03	2.861686E-01
19,	5		-1.578401E-02	-6.338675E-03	1.780603E-01
19,	4		-1.324659E-02	-4.903025E-03	1.231290E-01
19,	3		-9.636059E-03	-3.359861E-03	6.997208E-02
19,	2		-5.067179E-03	-1.713557E-03	2.523418E-02
19,	1		-2.589518E-03	-8.672638E-04	7.664569E-03
19,	-0	BCUNDARY	0.	0.	0.
19,	-1		2.620010E-03	8.860647E-04	7.664569E-03
19,	-2		0.	0.	3.608237E-02

SPHERE STRESS RESULTANTS,

ROW	COL	NX	NTHETA	NXTHETA	NTHETAX
7,	30	1.0666E-01	3.1256E-01	1.8012E-01	1.8012E-01
7,	31	9.4004E-02	3.1335E-01	1.9175E-01	1.9175E-01
8,	1	4.1548E-01	4.9208E-01	0.	0.
8,	2	4.1553E-01	4.9204E-01	1.0850E-03	1.0850E-03
8,	3	4.1566E-01	4.9192E-01	2.1802E-03	2.1802E-03
8,	4	4.1588E-01	4.9173E-01	3.2953E-03	3.2953E-03
8,	5	4.1619E-01	4.9145E-01	4.4417E-03	4.4417E-03
8,	6	4.1662E-01	4.9108E-01	5.6343E-03	5.6343E-03
8,	7	4.1721E-01	4.9062E-01	6.8937E-03	6.8937E-03
8,	8	4.1799E-01	4.9007E-01	8.2481E-03	8.2481E-03
8,	9	4.1901E-01	4.8942E-01	9.7361E-03	9.7361E-03
8,	10	4.2033E-01	4.8865E-01	1.1409E-02	1.1409E-02
8,	11	4.2202E-01	4.8777E-01	1.3331E-02	1.3331E-02
8,	12	4.2413E-01	4.8674E-01	1.5584E-02	1.5584E-02
8,	13	4.2670E-01	4.8555E-01	1.8265E-02	1.8265E-02
8,	14	4.2975E-01	4.8417E-01	2.1481E-02	2.1481E-02

Table 5 (cont'd)

8,	15	4.3322E-01	4.8256E-01	2.5349E-02	2.5349E-02
8,	16	4.3699E-01	4.8068E-01	2.9978E-02	2.9978E-02
8,	17	4.4079E-01	4.7845E-01	3.5459E-02	3.5459E-02
8,	18	4.4419E-01	4.7582E-01	4.1842E-02	4.1842E-02
8,	19	4.4655E-01	4.7268E-01	4.9109E-02	4.9109E-02
8,	20	4.4694E-01	4.6895E-01	5.7146E-02	5.7146E-02
8,	21	4.4417E-01	4.6452E-01	6.5720E-02	6.5720E-02
8,	22	4.3677E-01	4.5927E-01	7.4460E-02	7.4460E-02
8,	23	4.2304E-01	4.5309E-01	8.2873E-02	8.2873E-02
8,	24	4.0125E-01	4.4589E-01	9.0384E-02	9.0384E-02
8,	25	3.6991E-01	4.3757E-01	9.6441E-02	9.6441E-02
8,	26	3.2827E-01	4.2804E-01	1.0068E-01	1.0068E-01
8,	27	2.7705E-01	4.1721E-01	1.0312E-01	1.0312E-01
8,	28	2.1947E-01	4.0492E-01	1.0444E-01	1.0444E-01
8,	29	1.6251E-01	3.9095E-01	1.0609E-01	1.0609E-01
8,	30	1.1856E-01	3.7494E-01	1.1031E-01	1.1031E-01
8,	31	1.1186E-01	3.7287E-01	1.1898E-01	1.1898E-01
9,	1	4.0953E-01	5.1282E-01	0.	0.
9,	2	4.0958E-01	5.1279E-01	3.6104E-04	3.6104E-04
9,	3	4.0973E-01	5.1267E-01	7.2488E-04	7.2488E-04
9,	4	4.0998E-01	5.1246E-01	1.0946E-03	1.0946E-03
9,	5	4.1034E-01	5.1217E-01	1.4736E-03	1.4736E-03
9,	6	4.1084E-01	5.1179E-01	1.8661E-03	1.8661E-03
9,	7	4.1152E-01	5.1131E-01	2.2768E-03	2.2768E-03
9,	8	4.1242E-01	5.1073E-01	2.7111E-03	2.7111E-03

SPHERE STRESS RESULTANTS.

ROW	COL	MX	MTHETA	MXTHETA	QX	QTHETA
7,	30	-1.8034E 01	-6.6409E 01	-6.3016E 00	3.9493E 01	-3.2650E 03
7,	31	-4.3271E 01	-1.4424E 02	-1.9175E-01	1.1332E 02	-3.7978E 03
8,	1	1.4440E 01	4.1252E 00	0.	4.8136E 01	2.0322E-05
8,	2	1.4450E 01	4.1492E 00	2.8456E-02	4.8305E 01	6.7031E-01
8,	3	1.4456E 01	4.1439E 00	5.7105E-02	4.8467E 01	-5.3604E-01
8,	4	1.4459E 01	4.1103E 00	8.8090E-02	4.8636E 01	-1.6947E 00
8,	5	1.4460E 01	4.0489E 00	1.2348E-01	4.8820E 01	-2.7939E 00
8,	6	1.4460E 01	3.9603E 00	1.6520E-01	4.9025E 01	-3.7863E 00
8,	7	1.4460E 01	3.8464E 00	2.1487E-01	4.9254E 01	-4.5651E 00
8,	8	1.4464E 01	3.7113E 00	2.7354E-01	4.9504E 01	-4.9409E 00
8,	9	1.4477E 01	3.5639E 00	3.4131E-01	4.9767E 01	-4.6206E 00
8,	10	1.4507E 01	3.4198E 00	4.1674E-01	5.0022E 01	-3.1864E 00
8,	11	1.4563E 01	3.3043E 00	4.9617E-01	5.0236E 01	-7.5807E-02
8,	12	1.4661E 01	3.2559E 00	5.7280E-01	5.0357E 01	5.4176E 00
8,	13	1.4817E 01	3.3298E 00	6.3573E-01	5.0313E 01	1.4113E 01
8,	14	1.5055E 01	3.5998E 00	6.6901E-01	5.0000E 01	2.6885E 01
8,	15	1.5399E 01	4.1605E 00	6.5092E-01	4.9288E 01	4.4558E 01
8,	16	1.5875E 01	5.1257E 00	5.5373E-01	4.8016E 01	6.7715E 01
8,	17	1.6506E 01	6.6226E 00	3.4453E-01	4.5998E 01	9.6405E 01

8,	18	1.7305E 01	8.7797E 00	-1.2557E-02	4.3033E 01	1.2975E 02
8,	19	1.8270E 01	1.1705E 01	-5.5192E-01	3.8932E 01	1.6538E 02
8,	20	1.9365E 01	1.5449E 01	-1.2993E 00	3.3554E 01	1.9877E 02
8,	21	2.0513E 01	1.9955E 01	-2.2616E 00	2.6866E 01	2.2244E 02
8,	22	2.1569E 01	2.4989E 01	-3.4135E 00	1.9017E 01	2.2506E 02
8,	23	2.2308E 01	3.0042E 01	-4.6830E 00	1.0435E 01	1.9068E 02
8,	24	2.2397E 01	3.4225E 01	-5.9383E 00	1.9232E 00	9.8242E 01
8,	25	2.1385E 01	3.6142E 01	-6.9821E 00	-5.2742E 00	-7.8293E 01
8,	26	1.8690E 01	3.3776E 01	-7.5634E 00	-9.4875E 00	-3.6866E 02
8,	27	1.3609E 01	2.4408E 01	-7.4186E 00	-8.8120E 00	-8.0323E 02
8,	28	5.3436E 00	4.6353E 00	-6.3573E 00	-1.5812E 00	-1.4073E 03
8,	29	-6.9531E 00	-2.9455E 01	-4.4022E 00	1.2757E 01	-2.1924E 03
8,	30	-2.4093E 01	-8.1850E 01	-1.9791E 00	3.2301E 01	-3.1434E 03
8,	31	-4.6744E 01	-1.5581E 02	-1.1898E-01	5.0972E 01	-3.6314E 03
9,	1	1.0706E 01	2.7788E 00	0.	4.7328E 00	2.0558E-05
9,	2	1.0717E 01	2.8047E 00	5.5560E-03	5.0009E 00	7.0565E-01
9,	3	1.0724E 01	2.7964E 00	1.1408E-02	5.2746E 00	-6.7898E-01
9,	4	1.0729E 01	2.7549E 00	1.8096E-02	5.5704E 00	-1.9872E 00
9,	5	1.0732E 01	2.6814E 00	2.6100E-02	5.9019E 00	-3.1939E 00
9,	6	1.0734E 01	2.5774E 00	3.5800E-02	6.2796E 00	-4.2344E 00
9,	7	1.0739E 01	2.4462E 00	4.7404E-02	6.7091E 00	-4.9696E 00
9,	8	1.0750E 01	2.2943E 00	6.0844E-02	7.1881E 00	-5.1727E 00

BOUNDARY STRESS RESULTANTS.

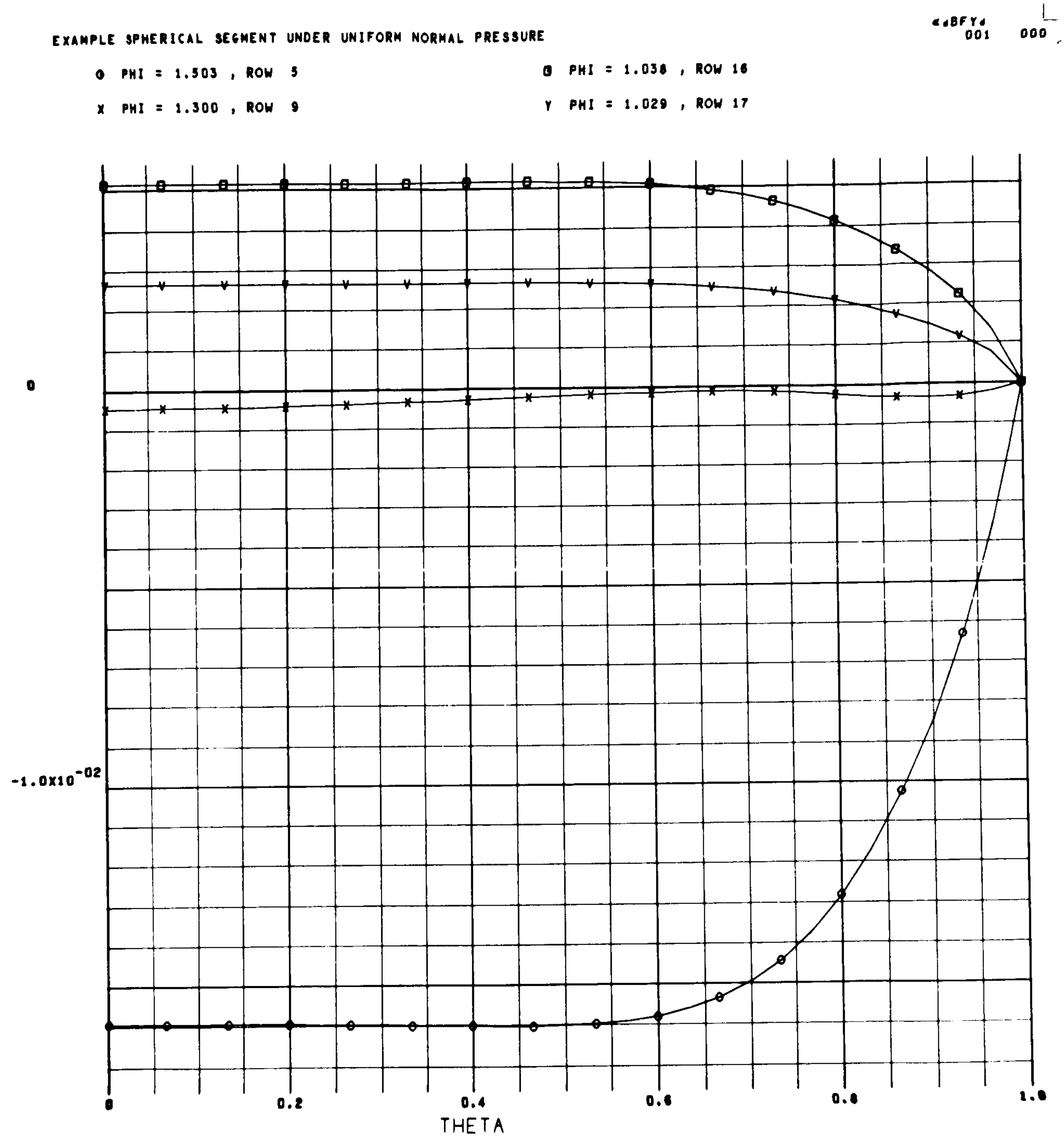
ROW	COL	NTAN	NNORM	Q	M
18,	1	0.	3.1654E-01	-8.3278E 03	-1.9934E 02
18,	2	-2.8194E-03	3.1655E-01	-8.3267E 03	-1.9937E 02
18,	3	-5.6834E-03	3.1656E-01	-8.3274E 03	-1.9944E 02
18,	4	-8.6365E-03	3.1658E-01	-8.3296E 03	-1.9956E 02
18,	5	-1.1726E-02	3.1661E-01	-8.3332E 03	-1.9972E 02
18,	6	-1.5005E-02	3.1666E-01	-8.3385E 03	-1.9995E 02
18,	7	-1.8534E-02	3.1671E-01	-8.3457E 03	-2.0025E 02
18,	8	-2.2385E-02	3.1677E-01	-8.3555E 03	-2.0065E 02
18,	9	-2.6642E-02	3.1684E-01	-8.3686E 03	-2.0116E 02
18,	10	-3.1405E-02	3.1691E-01	-8.3861E 03	-2.0183E 02
18,	11	-3.6790E-02	3.1697E-01	-8.4092E 03	-2.0268E 02
18,	12	-4.2930E-02	3.1699E-01	-8.4394E 03	-2.0374E 02
18,	13	-4.9972E-02	3.1694E-01	-8.4785E 03	-2.0504E 02
18,	14	-5.8073E-02	3.1676E-01	-8.5283E 03	-2.0660E 02
18,	15	-6.7390E-02	3.1638E-01	-8.5906E 03	-2.0843E 02
18,	16	-7.8067E-02	3.1568E-01	-8.6666E 03	-2.1049E 02
18,	17	-9.0212E-02	3.1452E-01	-8.7569E 03	-2.1269E 02
18,	18	-1.0387E-01	3.1269E-01	-8.8602E 03	-2.1489E 02

Table 5 (cont'd)

18,	19	-1.1899E-01	3.0996E-01	-8.9730E 03	-2.1682E 02
18,	20	-1.3537E-01	3.0607E-01	-9.0883E 03	-2.1812E 02
18,	21	-1.5260E-01	3.0064E-01	-9.1941E 03	-2.1823E 02
18,	22	-1.7003E-01	2.9327E-01	-9.2718E 03	-2.1646E 02
18,	23	-1.8669E-01	2.8354E-01	-9.2945E 03	-2.1188E 02
18,	24	-2.0125E-01	2.7100E-01	-9.2247E 03	-2.0338E 02
18,	25	-2.1202E-01	2.5518E-01	-9.0124E 03	-1.8972E 02
18,	26	-2.1695E-01	2.3562E-01	-8.5922E 03	-1.6964E 02
18,	27	-2.1369E-01	2.1185E-01	-7.8802E 03	-1.4214E 02
18,	28	-1.9971E-01	1.8329E-01	-6.7676E 03	-1.0698E 02
18,	29	-1.7204E-01	1.4896E-01	-5.1084E 03	-6.5787E 01
18,	30	-1.2332E-01	1.0458E-01	-2.7357E 03	-2.4507E 01
18,	31	0.	0.	-3.7534E 00	-0.
18,	31				
18,	31	-0.	0.	-0.	0.
17,	31	6.2429E-02	6.6763E-02	-1.8459E 02	-5.6682E 00
16,	31	1.0333E-01	1.0408E-01	-5.8460E 02	-1.7943E 01
15,	31	1.5904E-01	1.5705E-01	-1.5130E 03	-4.7199E 01
14,	31	1.8736E-01	1.9392E-01	-2.2564E 03	-7.4360E 01
13,	31	2.0035E-01	2.2494E-01	-2.7428E 03	-9.5980E 01
12,	31	2.0334E-01	2.8463E-01	-3.4037E 03	-1.3038E 02
11,	31	1.7540E-01	3.2177E-01	-3.5660E 03	-1.4594E 02
10,	31	9.3693E-02	3.7727E-01	-3.4916E 03	-1.5588E 02
9,	31	-1.3941E-02	3.8796E-01	-3.4799E 03	-1.5683E 02
8,	31	-1.1898E-01	3.7287E-01	-3.6314E 03	-1.5581E 02
7,	31	-1.9174E-01	3.1335E-01	-3.7978E 03	-1.4424E 02
6,	31	-2.1314E-01	2.7501E-01	-3.6301E 03	-1.2743E 02
5,	31	-2.0256E-01	2.1514E-01	-2.8917E 03	-9.1868E 01
4,	31	-1.8584E-01	1.8463E-01	-2.3600E 03	-7.0433E 01
3,	31	-1.5398E-01	1.4857E-01	-1.5637E 03	-4.4102E 01
2,	31	-9.6554E-02	9.7046E-02	-5.9817E 02	-1.6483E 01
1,	31	-5.6772E-02	6.1051E-02	-1.9192E 02	-5.1964E 00
0,	31	0.	0.	0.	0.
0,	31				
0,	31	-0.	-0.	-3.3510E 00	-0.
0,	30	1.2570E-01	1.0769E-01	-2.1392E 02	-3.0291E 01
0,	29	1.7161E-01	1.5369E-01	-2.1461E 03	-7.5918E 01
0,	28	1.9603E-01	1.8906E-01	-4.1497E 03	-1.1849E 02
0,	27	2.0635E-01	2.1778E-01	-5.8101E 03	-1.5281E 02
0,	26	2.0607E-01	2.4103E-01	-7.0648E 03	-1.7822E 02
0,	25	1.9817E-01	2.5964E-01	-7.9498E 03	-1.9574E 02
0,	24	1.8526E-01	2.7427E-01	-8.5311E 03	-2.0689E 02
0,	23	1.6945E-01	2.8556E-01	-8.8790E 03	-2.1324E 02
0,	22	1.5239E-01	2.9408E-01	-9.0566E 03	-2.1614E 02
0,	21	1.3526E-01	3.0037E-01	-9.1169E 03	-2.1673E 02

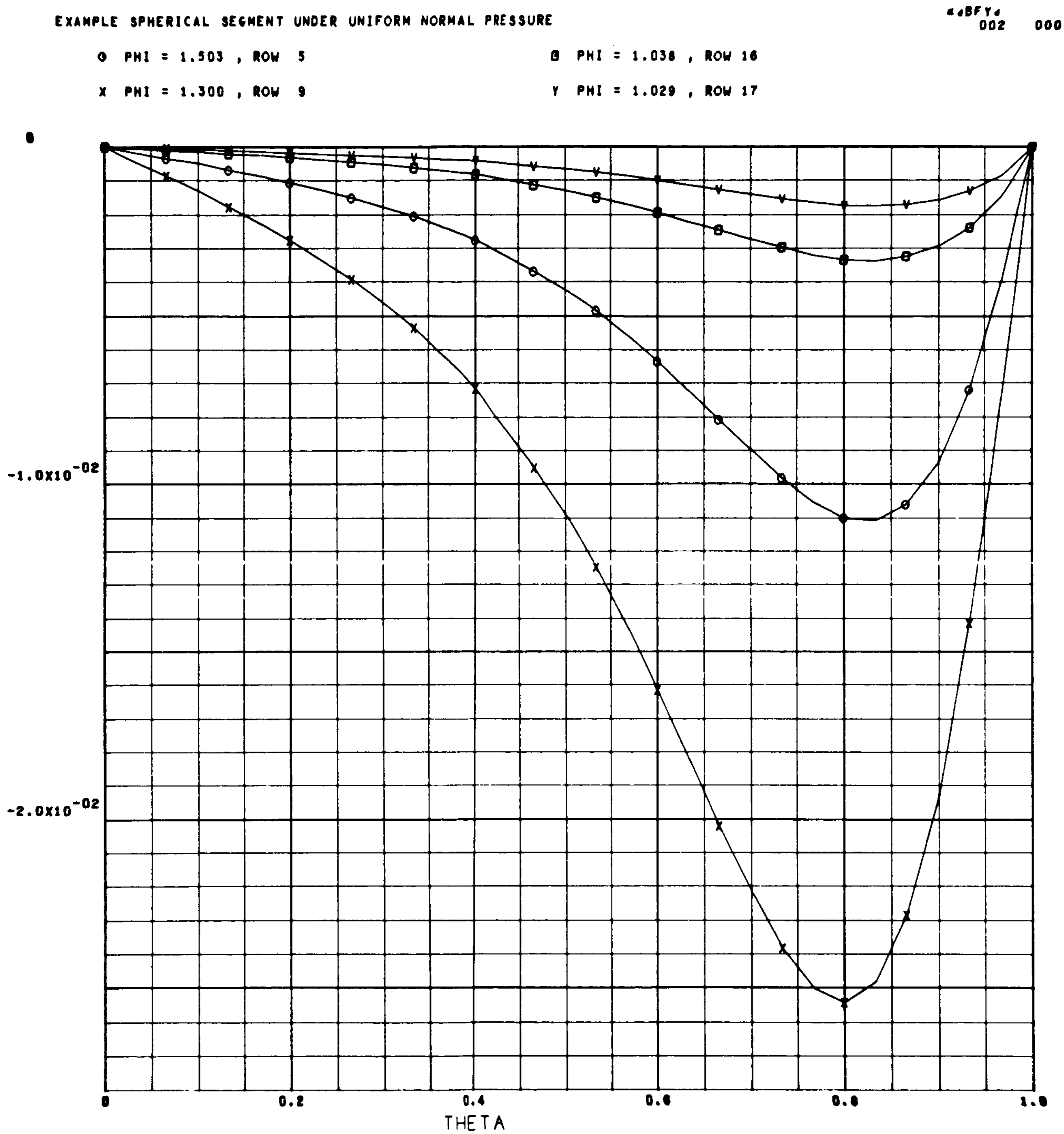
Table 5 (concl'd)

0,	20	1.1887E-01	3.0491E-01	-9.1010E	03	-2.1585E	02
0,	19	1.0370E-01	3.0810E-01	-9.0399E	03	-2.1416E	02
0,	18	9.0002E-02	3.1028E-01	-8.9560E	03	-2.1208E	02
0,	17	7.7856E-02	3.1173E-01	-8.8641E	03	-2.0992E	02
0,	16	6.7221E-02	3.1266E-01	-8.7739E	03	-2.0787E	02
0,	15	5.7985E-02	3.1324E-01	-8.6910E	03	-2.0602E	02
0,	14	4.9999E-02	3.1360E-01	-8.6181E	03	-2.0441E	02
0,	13	4.3097E-02	3.1380E-01	-8.5561E	03	-2.0306E	02
0,	12	3.7116E-02	3.1393E-01	-8.5046E	03	-2.0194E	02
0,	11	3.1904E-02	3.1400E-01	-8.4627E	03	-2.0104E	02
0,	10	2.7324E-02	3.1406E-01	-8.4292E	03	-2.0032E	02
0,	9	2.3258E-02	3.1410E-01	-8.4025E	03	-1.9975E	02
0,	8	1.9604E-02	3.1414E-01	-8.3816E	03	-1.9931E	02
0,	7	1.6279E-02	3.1418E-01	-8.3652E	03	-1.9896E	02
0,	6	1.3213E-02	3.1422E-01	-8.3524E	03	-1.9869E	02
0,	5	1.0347E-02	3.1425E-01	-8.3425E	03	-1.9849E	02
0,	4	7.6330E-03	3.1428E-01	-8.3350E	03	-1.9833E	02
0,	3	5.0287E-03	3.1430E-01	-8.3293E	03	-1.9823E	02
0,	2	2.4962E-03	3.1431E-01	-8.3251E	03	-1.9816E	02
0,	1	-0.	3.1431E-01	-8.3224E	03	-1.9813E	02

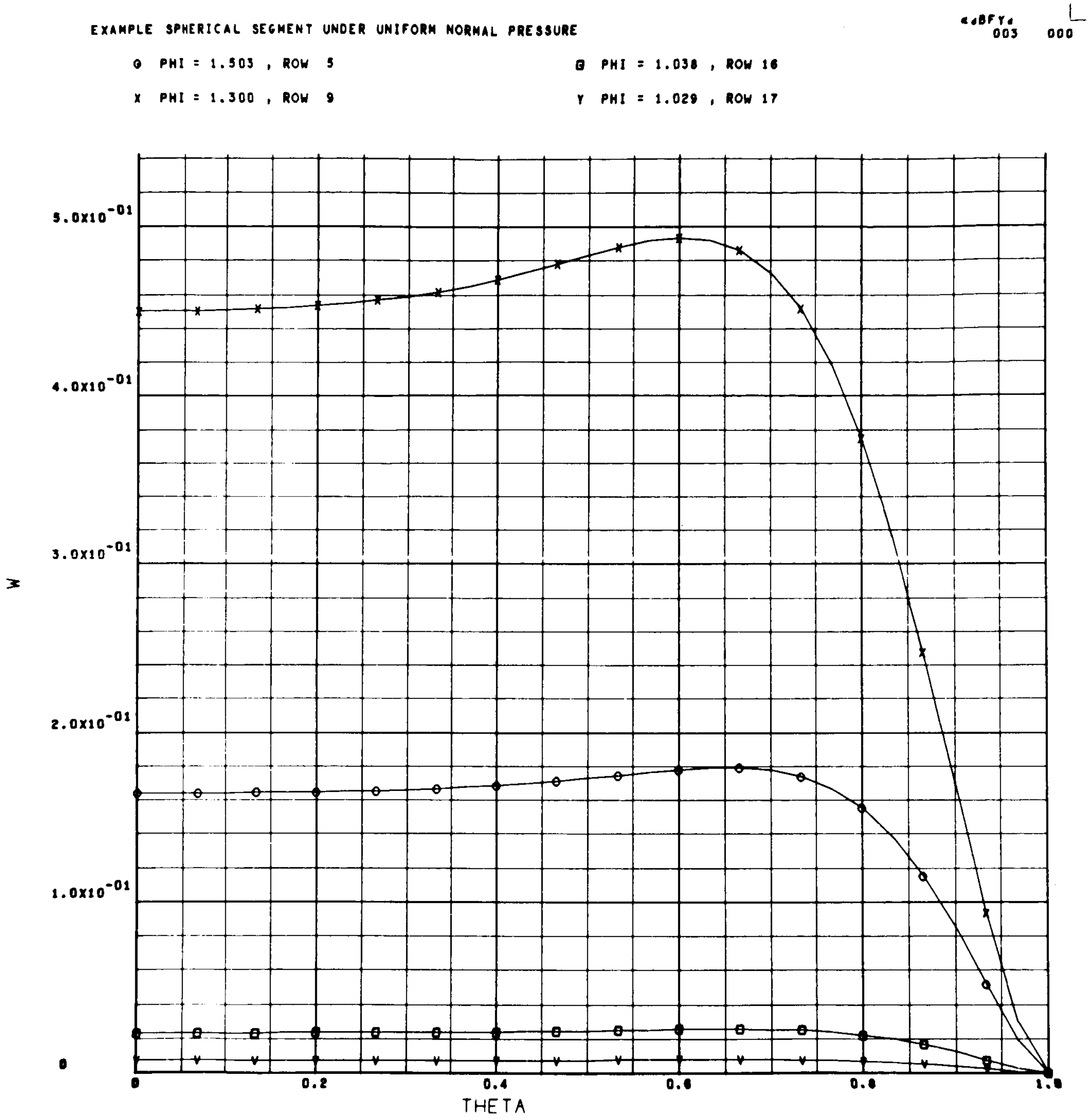


a – Sphere Displacement Components

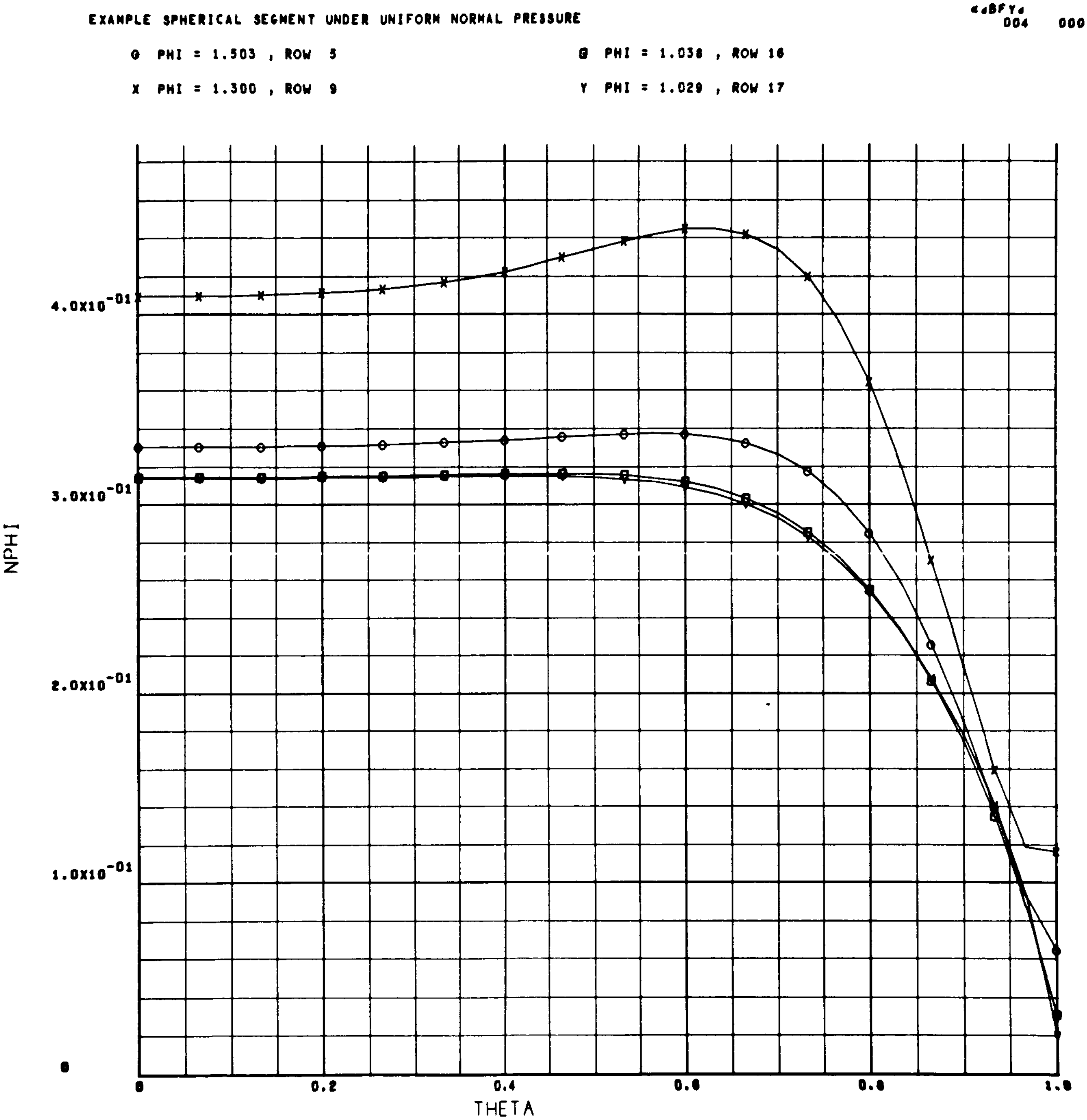
Fig. 12 Output Plot for the Example: Spherical Segment Under Uniform Normal Pressure



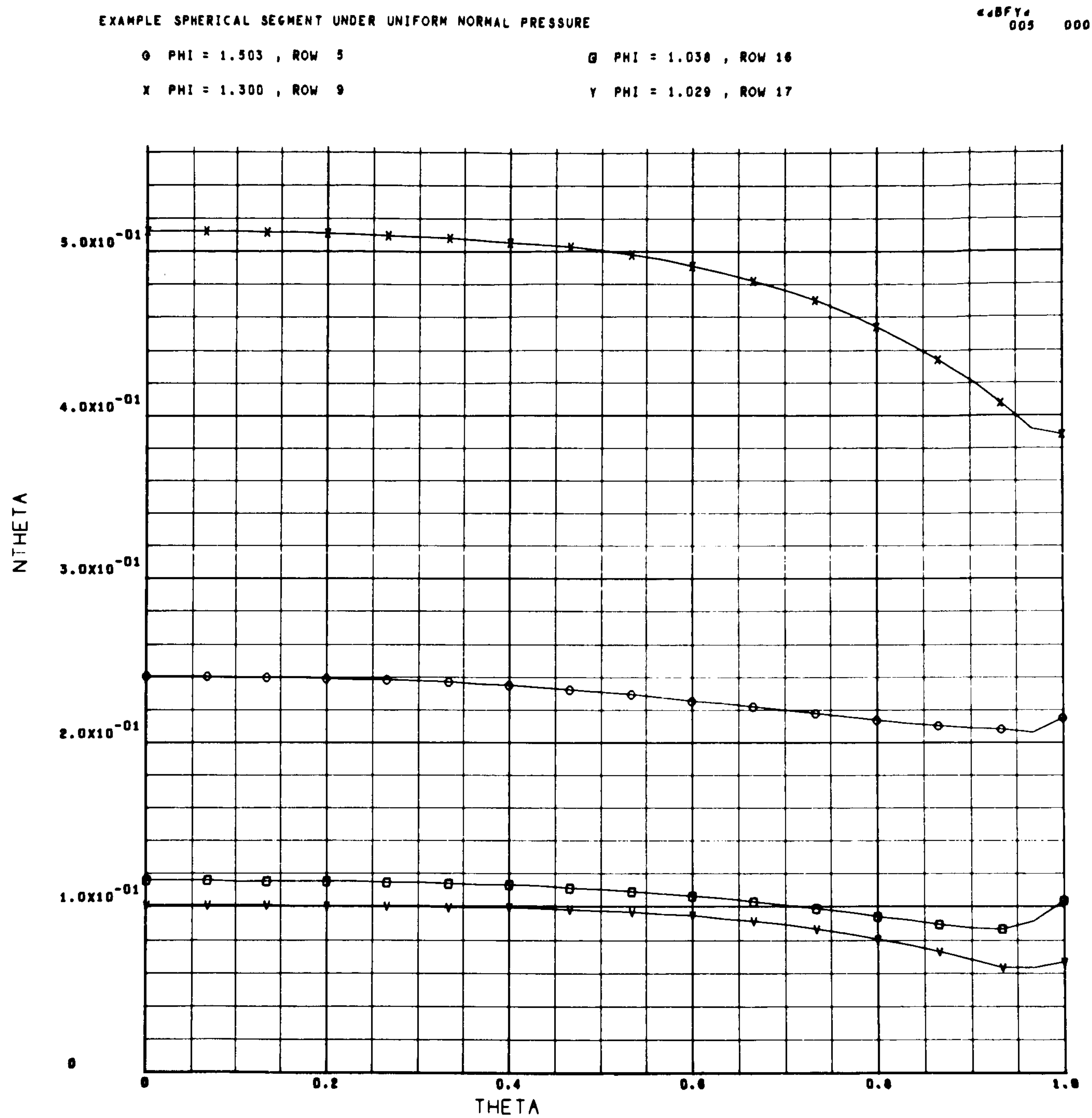
b — Sphere Displacement Components



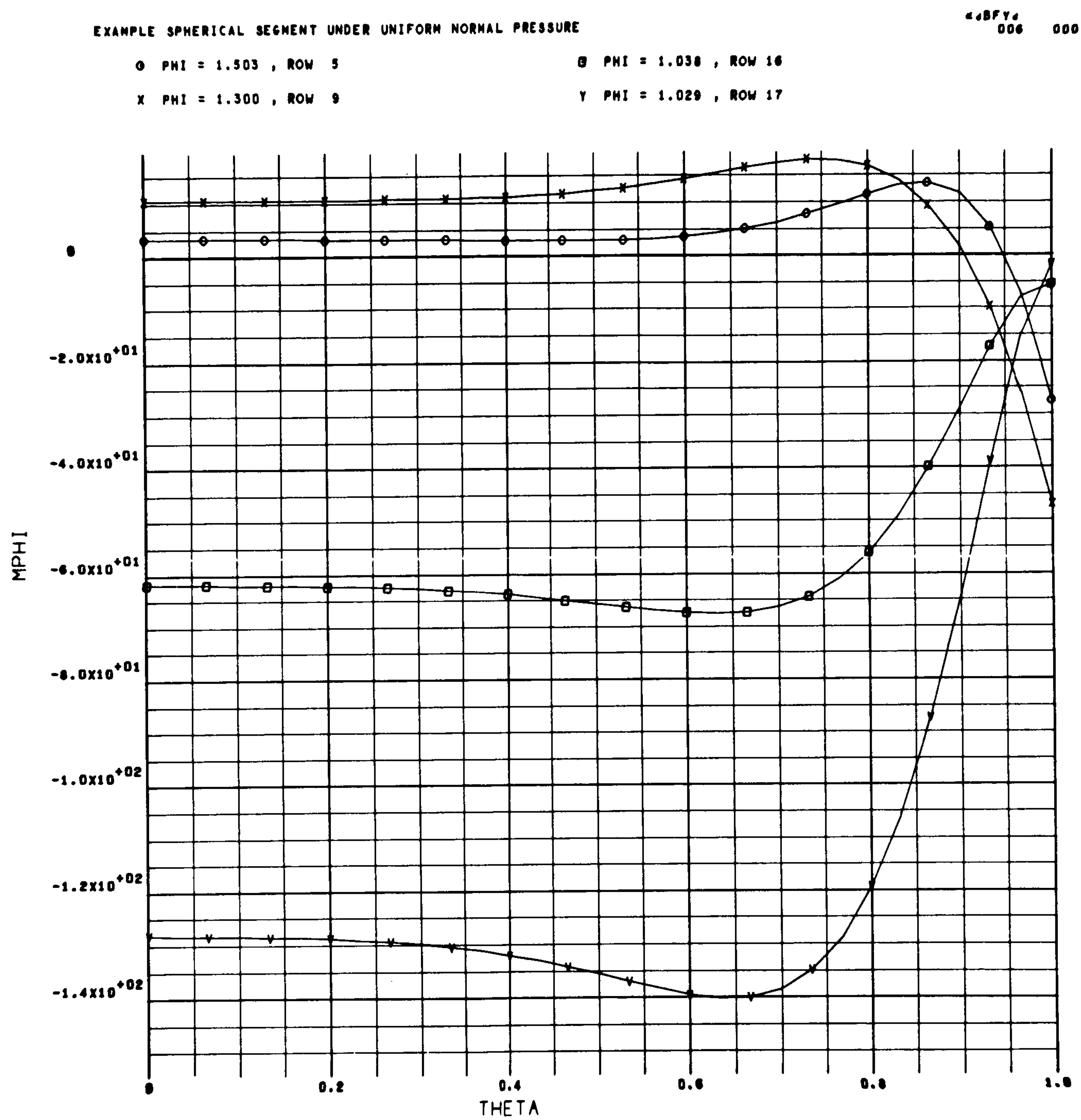
c – Sphere Displacement Components



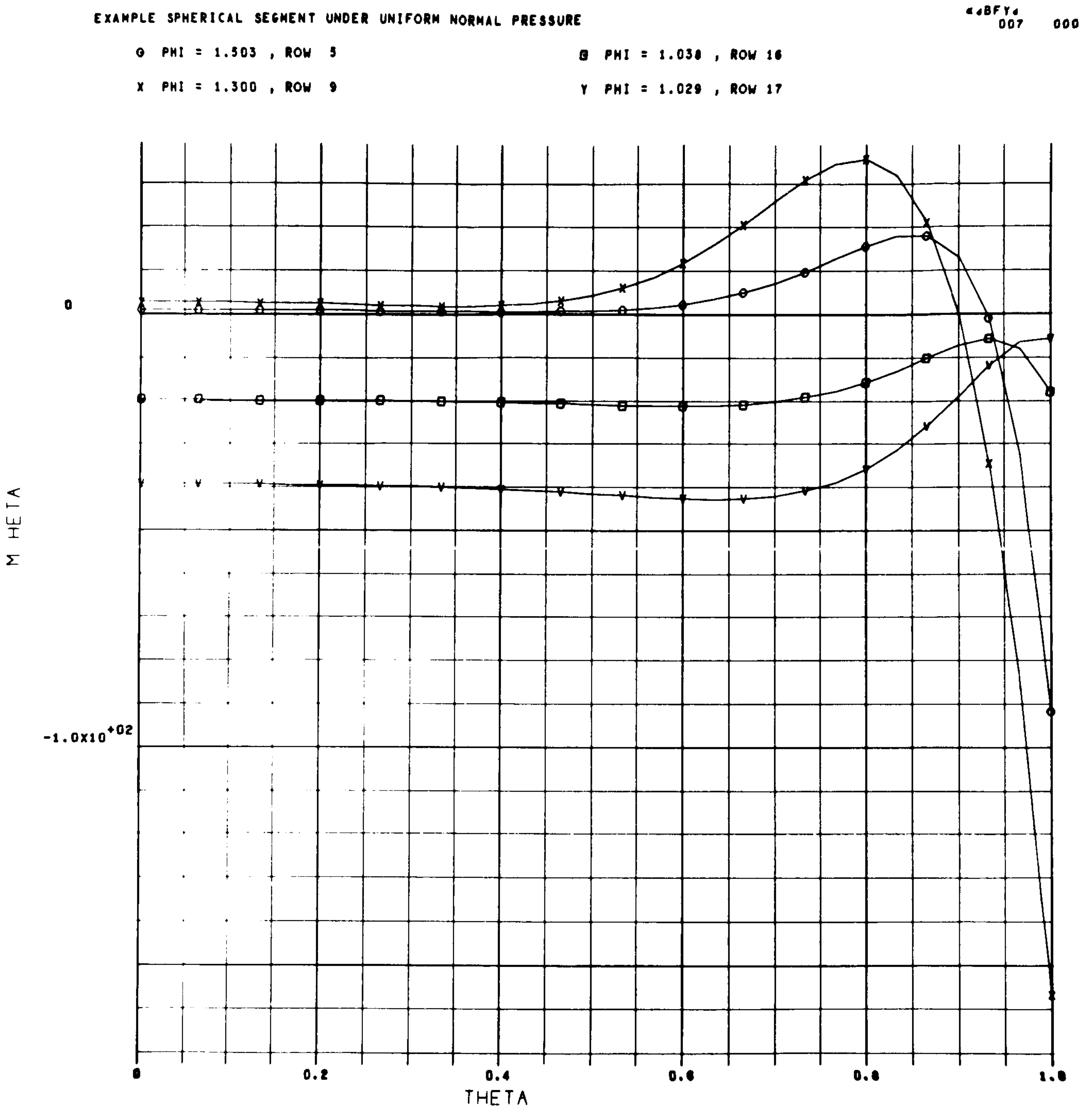
d — Sphere Stress Resultants



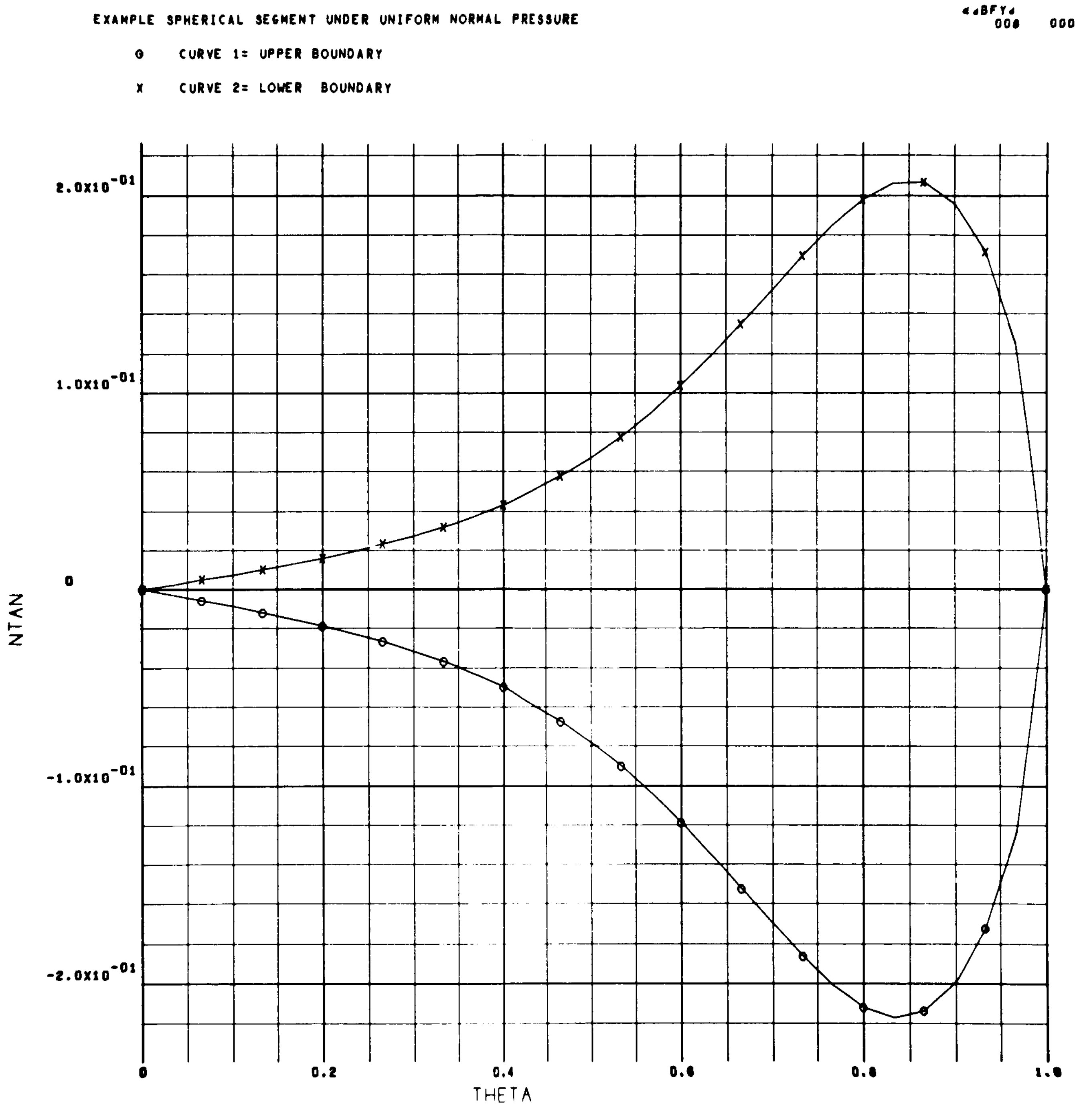
e — Sphere Stress Resultants



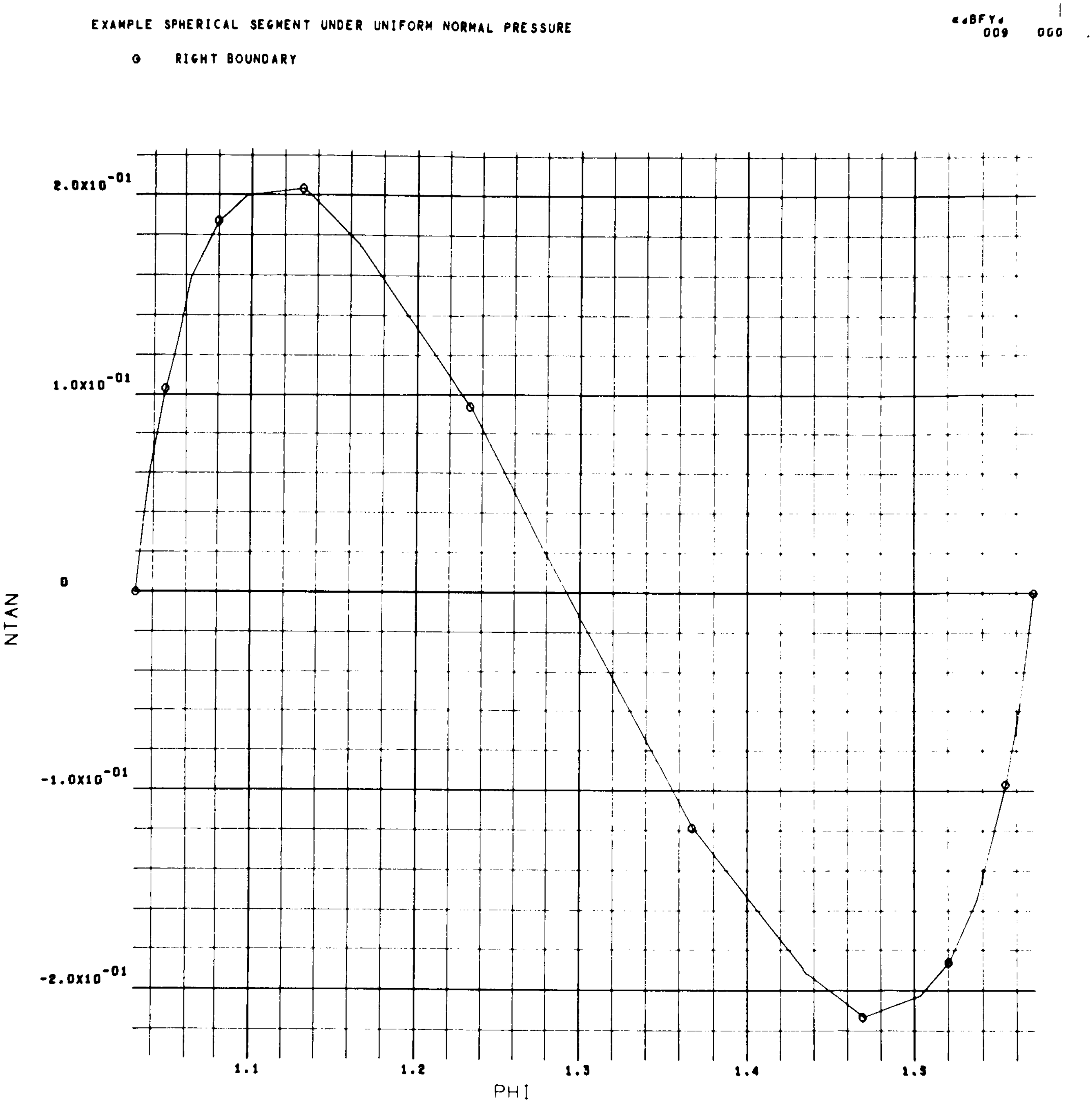
f – Sphere Stress Resultants



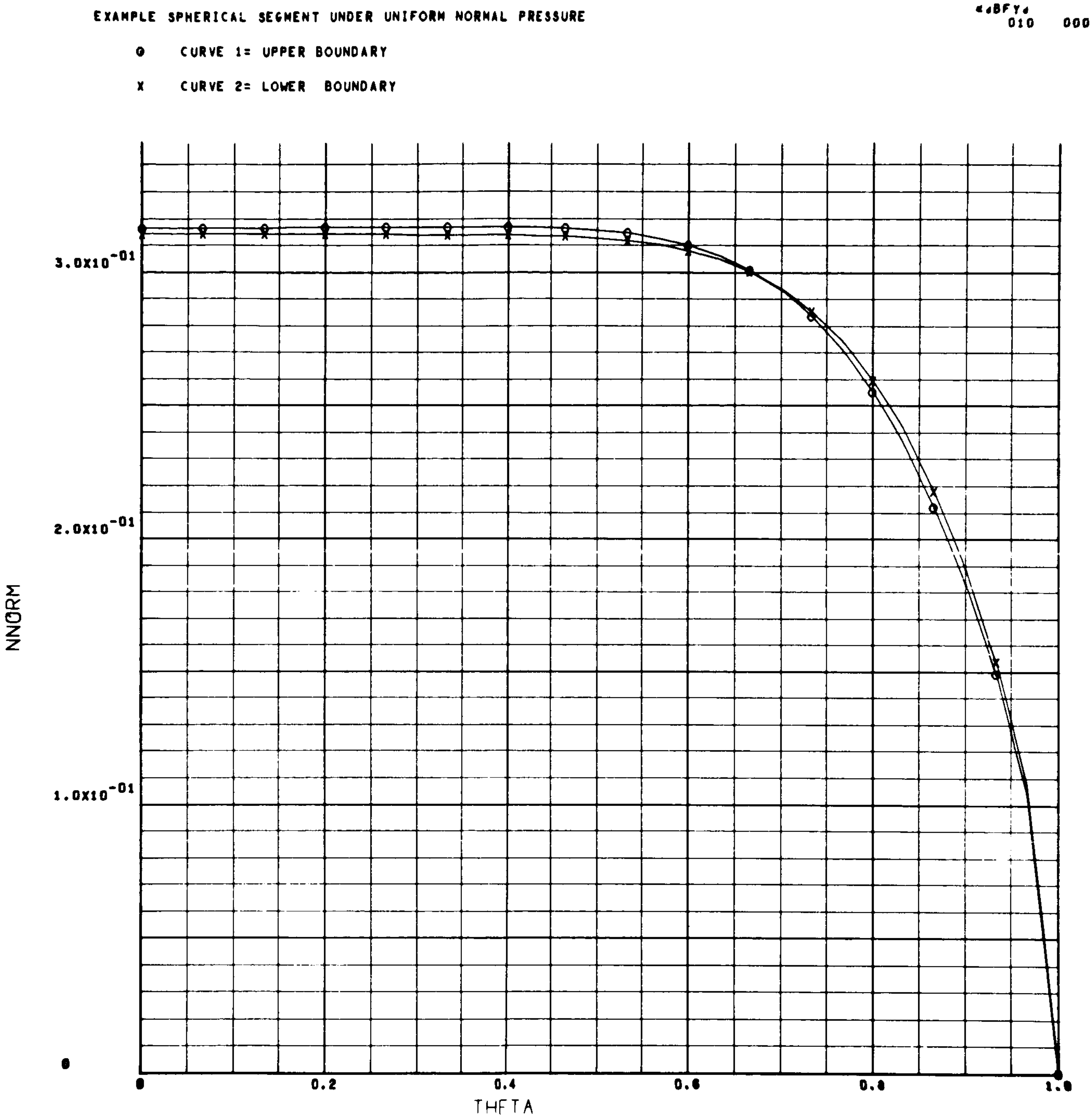
g – Sphere Stress Resultants



h — Boundary Stress Resultants

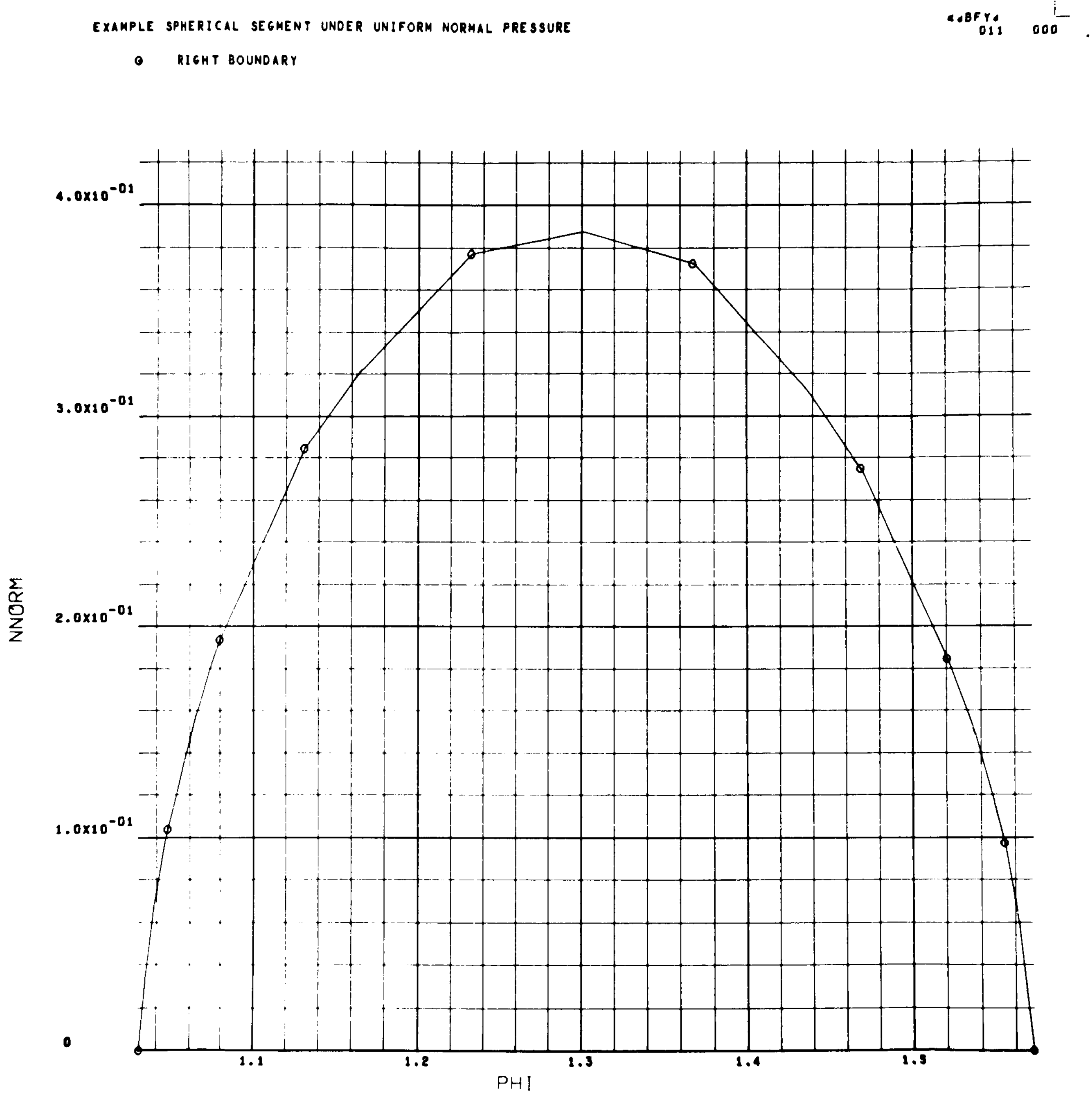


i – Boundary Stress Resultants

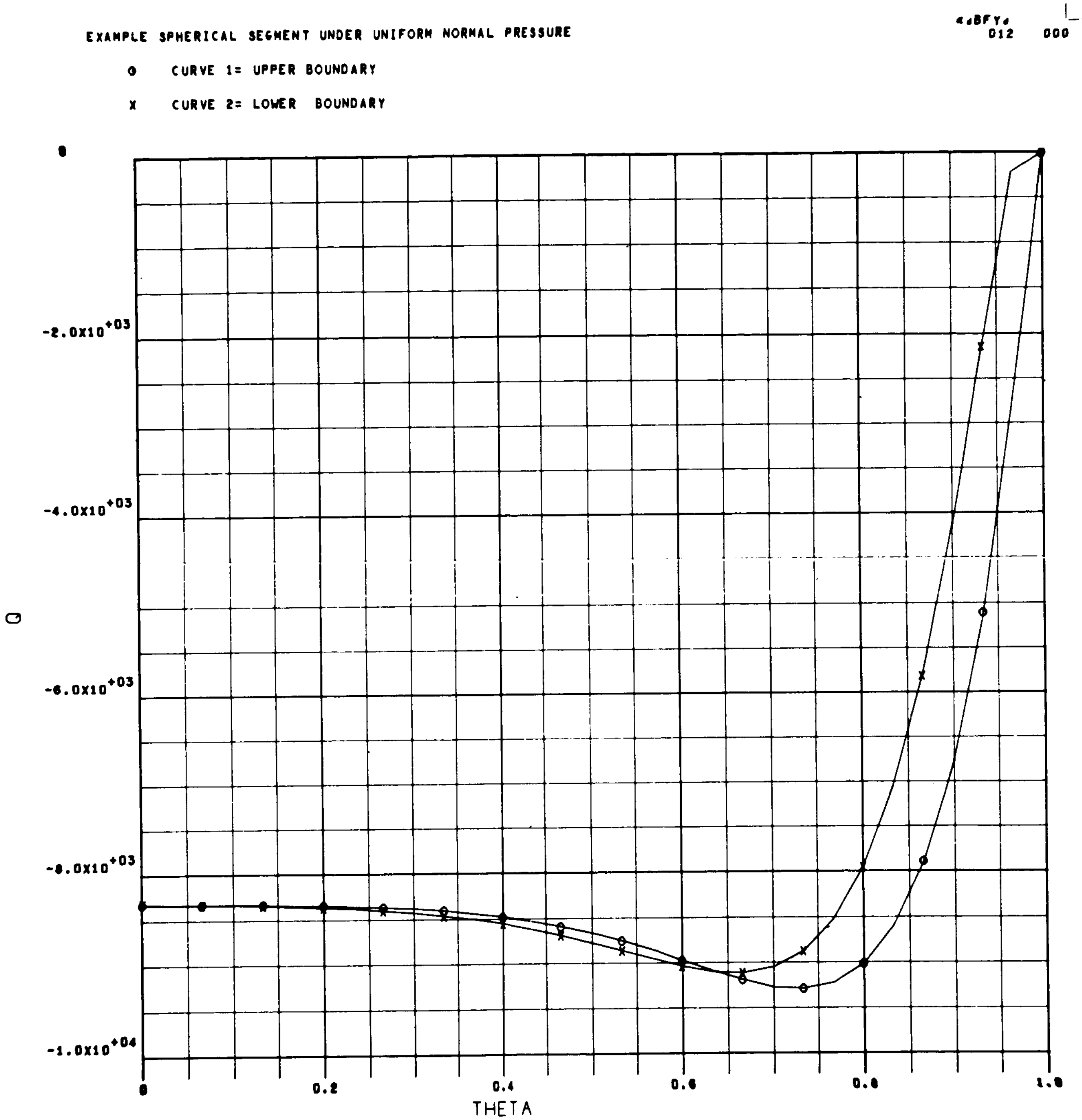


j – Boundary Stress Resultants

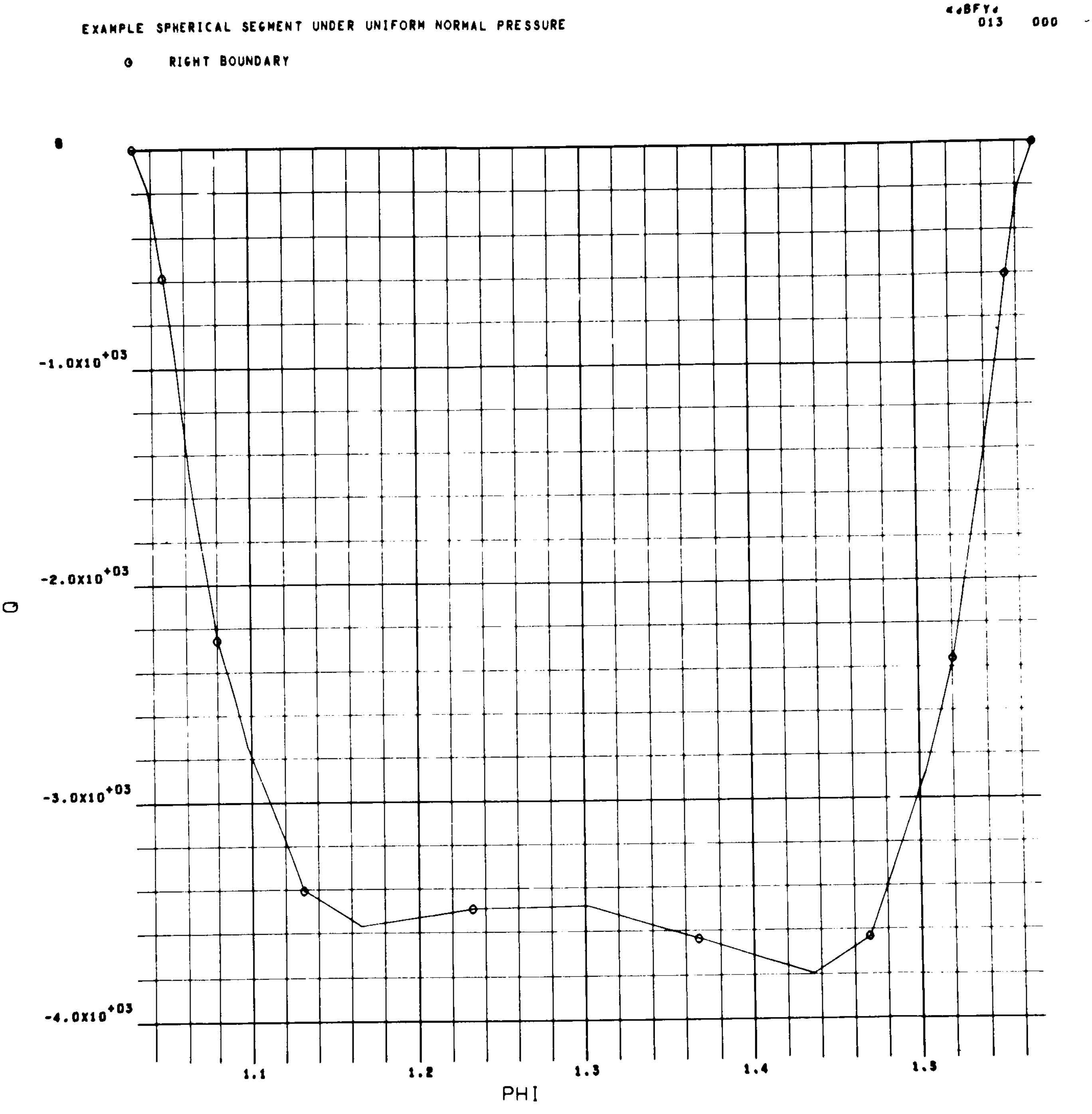
EXAMPLE SPHERICAL SEGMENT UNDER UNIFORM NORMAL PRESSURE



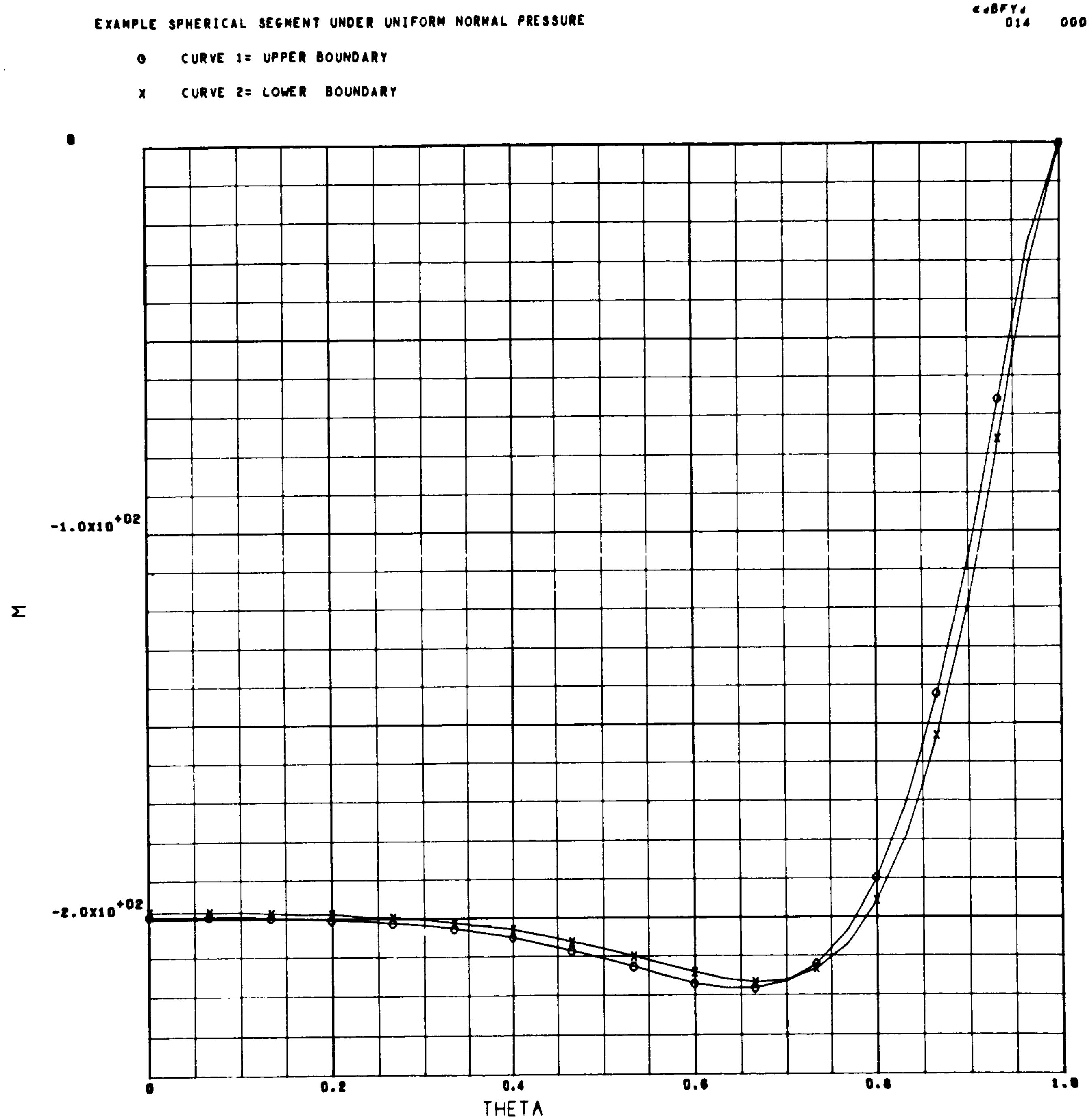
k – Boundary Stress Resultants



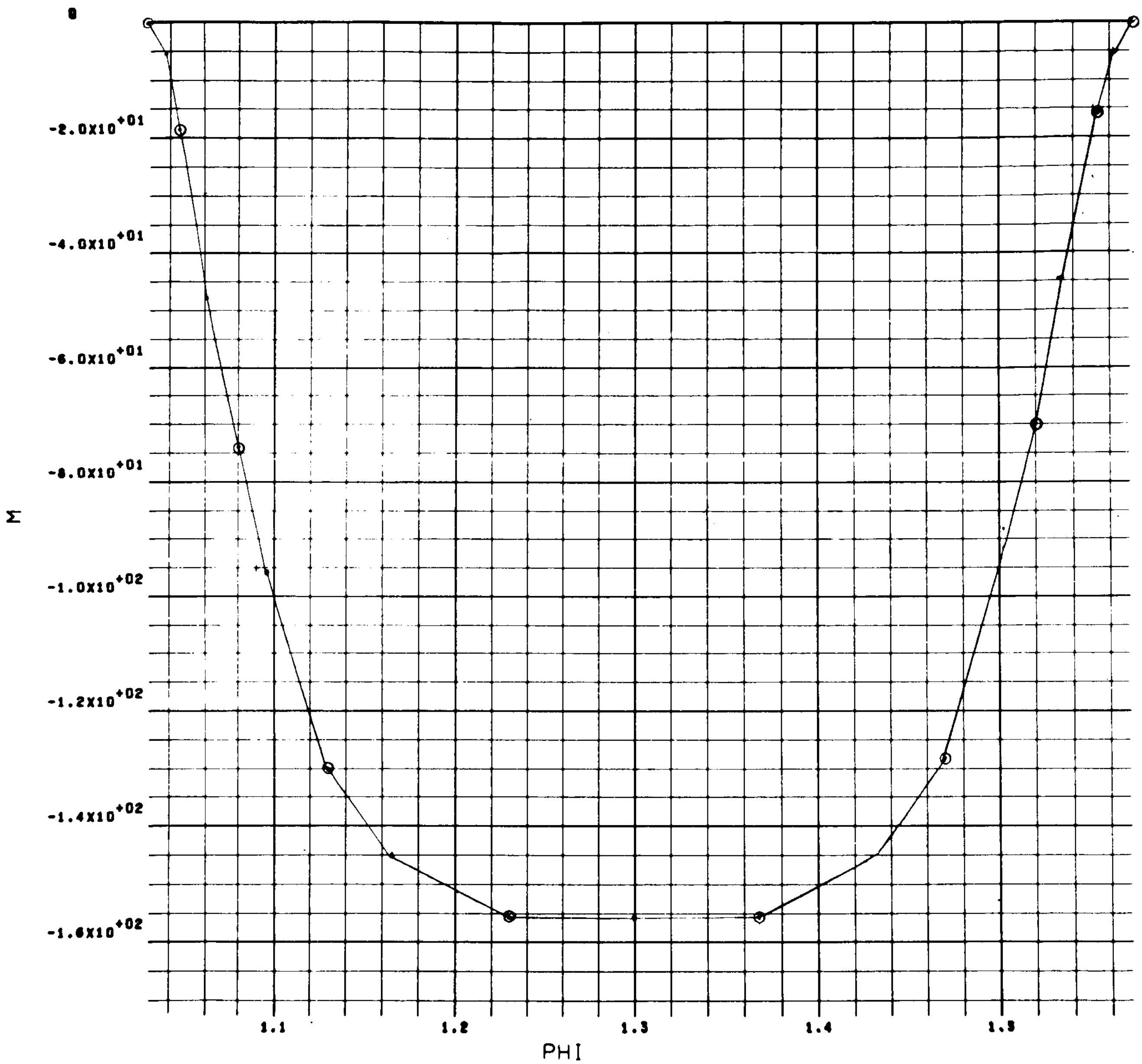
1 – Boundary Stress Resultants



m – Boundary Stress Resultants



n – Boundary Stress Resultants



o — Boundary Stress Resultants

4.3 LISTING OF THE PROGRAM

The complete program is given in Table 6.

Table 6

STUDY OF JUNCTURE STRESS FIELD: SPHERICAL SEGMENT

```
*      CHAIN(1,2)                                                      S1P00010
*      FORTRAN                                                         S1P00020
*      LIST                                                            S1P00030
CS1P   SPHERICAL SEGMENT ' STUDY OF JUNCTURE STRESS FIELD '            S1P00040
C CONTRACT NAS 8-114800 TO NASA G.C. MARSHALL SPACE FLIGHT CENTER       S1P00050
C                     HUNTSVILLE, ALABAMA                              S1P00060
C BY SOLID MECHANICS , AEROSPACE SCIENCES LABORATORY , 52-20           S1P00070
C LOCKHEED MISSILES AND SPACE COMPANY, PALO ALTO CALIF                 S1P00080
C      THIS PROGRAM IS FOR USE ONLY ON FORTRAN II, VERSION II          S1P00090
       COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8   S1P00100
       COMMON NCF                                                      S1P00110
       COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                      S1P00120
       COMMON ISW1, ISW2, ISW3                                         S1P00130
       COMMON A                                                        S1P00140
       COMMON  TMP, YK, YL                                             S1P00150
       COMMON T1, T2, XX, XX1, Z, Z1, Z2                               S1P00160
       COMMON ZNU, THC, PH1, FF, RH, DD, XH, XK                        S1P00170
       COMMON ZETA                                                     S1P00180
       COMMON TE, TI, TO, OC, TC, TD, DDLD                             S1P00190
       COMMON RECORD                                                   S1P00200
       COMMON TIM1,TIM2, KTIME                                         S1P00210
       DIMENSION A(1232)                                               S1P00220
       DIMENSION MM(40)                                                S1P00230
       DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89) S1P00240
       DIMENSION TMP(5184), YK(5184), YL(4,4,324)                      S1P00250
       DIMENSION ZETA (30)                                             S1P00260
       DIMENSION RECORD (12)                                           S1P00270
     1 FORMAT (1H1, 12A6)                                              S1P00280
     2 FORMAT (6E12.8)                                                 S1P00290
     3 FORMAT (1H1)                                                    S1P00300
     4 FORMAT (35I2)                                                   S1P00310
     5 FORMAT (1H1,3X,3HCOL ,  I5, 8I14/4H ROW)                        S1P00320
     6 FORMAT ( I4, 1P9E14.6)                                          S1P00330
     7 FORMAT (10I1 )                                                  S1P00340
```

```
    8 FORMAT (12A6)                                                      S1P00350
   14 FORMAT (26H0  FINITE DIFFERENCE MESH. I2, 7H ROWS,  I2,27H COLUMNSS1P00360
     1.  MESH SPACING. H= F15.7, 4H, K= E15.7 )                          S1P00370
   15 FORMAT (21H0INPUT CONSTANTS. NU= 1PE12.5, 9H, THETAC= 1PE12.5,     S1P00380
     1    7H, PHI1= 1PE12.5, 12H, PHI1/PHI2= 1PE12.5, 6H, R/H= 1PE12.5)  S1P00390
   17 FORMAT ( 42H0 SPHERE DISPLACEMENT COMPONENTS (U,V,W)     /         S1P00400
     1 10H0 COL  ROW   , 17X, 1HU, 15X, 1HV, 15X, 1HW  )                 S1P00410
   18 FORMAT (53H ROW COL     NX         NTHETA      NXTHETA     NTHETAX )S1P00420
   19 FORMAT (125H0ROW COL      EPSX        EPST             GAMMA      R*S1P00430
     1X1           R*X2          R*X12         OMEGAX      OMEGAT       PS1P00440
     2HI                  )                                              S1P00450
   20 FORMAT (28H0 SPHERE STRESS RESULTANTS.      )                      S1P00460
  919 FORMAT (34H  GRADED MESH IN ZETA DIRECTION      )                  S1P00470
  920 FORMAT ( 2X, 4H ROW, 15I8/ 6X, 15I8)                               S1P00480
  921 FORMAT ( 6H ZETA= , 15F8.5/ 6X, 15F8.5 )                           S1P00490
  922 FORMAT (27H  ROW 1 IS A SYMMETRY LINE    )                         S1P00500
  925 FORMAT (25H0UNIFORM RADIAL PRESSURE      )                         S1P00510
  930 FORMAT (1H I3, 1H, I3,             10X, 1P3E16.6 )                 S1P00520
  931 FORMAT (1H I3, 1H, I3,10H  BOUNDARY   , 1P3E16.6 )                 S1P00530
  932 FORMAT (1H I3, 1H, I3,10H SMTY LINE   ,1P3E16.6 )                  S1P00540
  936 FORMAT (30H0 BOUNDARY STRESS RESULTANTS.   /84H0ROW COL   NTAN     S1P00550
     1    NNORM          Q            M            RBAR                )S1P00560
  937 FORMAT(I3,1H, I3, 1P5E12.4 )                                       S1P00570
  938 FORMAT ( I3, 2H,  I3, 66X, 1PE16.7  )                              S1P00580
  939 FORMAT (59H0  SPHERE    STRAINS,  CHANGES OF CURVATURE AND ROTATIOS1P00590
     1N.      )                                                          S1P00600
  945 FORMAT ( 1H0 // 8H CASE NR I2,13H COMPLETED IN F8.3, 9H MINUTES.) S1P00610
  951 FORMAT (33H0LINEAR TEMPERATURE GRADIENT. TE=E15.7,5H, TI=E15.7,    S1P00620
     1 5H, TO=E15.7, 5H, OC=E15.7)                                       S1P00630
  962 FORMAT (90H ROW COL     MX         MTHETA      MXTHETA      QX     S1P00640
     1    QTHETA                                                       ) S1P00650
C     SET TAPE ASSIGNMENTS.                                              S1P00660
      KTAPE=15                                                           S1P00670
      MTAPE=7                                                            S1P00680
B     XMTP=000000002221                                                  S1P00690
B     XZTP=000000002223                                                  S1P00700
B     XNTP=000000001224                                                  S1P00710
      NTAPE=4                                                            S1P00720
      IZTAPE=3                                                           S1P00730
```

```
      REWIND MTAPE                                                      S1P00740
      REWIND NTAPE                                                      S1P00750
      REWIND IZTAPE                                                     S1P00760
      CALL CLOCK (TIM1)                                                 S1P00770
      NCF = 44                                                          S1P00780
C     READ AND WRITE INPUT DATA                                         S1P00790
   21 READ INPUT TAPE 5, 8, RECORD                                      S1P00800
      WRITE OUTPUT TAPE 6, 1, RECORD                                    S1P00810
C     IOPT1 = 0 CONSTANT MESH SPACING                                   S1P00820
C     IOPT1 = 1 GRADED MESH SPACING IN X DIRECTION                      S1P00830
C     IOPT2=0     SYMMETRY LINE AT PHI=PH1/2*(1+FF)                     S1P00840
C     IOPT2=1     NO SYMMETRY LINE                                      S1P00850
C     IOPT3 = 0 OMIT SPHERE STRAINS,CHANGES IN CURVATURE AND ROTATION   S1P00860
C     IOPT3 = 1 PRINT OUT STRAINS , ETC.                                S1P00870
C     IOPT4=0    UNIFORM NORMAL PRESSURE                                S1P00880
C     IOPT4=1    LINEAR TEMPERATURE GRADIENT                            S1P00890
C     IOPT5=0    NOT FINAL CASE WITH PLOTS                              S1P00900
C     IOPT5=1    FINAL CASE WITH PLOTS                                  S1P00910
      READ INPUT TAPE 5, 7, IOPT1,IOPT2, IOPT3, IOPT4, IOPT5,IOPT6,IOPT7S1P00920
     1 , IOPT8                                                          S1P00930
      XM = IOPT1                                                        S1P00940
      XLD=IOPT4                                                         S1P00950
      READ INPUT TAPE 5, 2, ROW, COL, XH, XK                            S1P00960
      READ INPUT TAPE 5, 2, ZNU, THC, PH1, FF, RH                       S1P00970
      NROW=ROW                                                          S1P00980
      NCOL=COL                                                          S1P00990
      NC1=NCOL+1                                                        S1P01000
      NR1=NROW+1                                                        S1P01010
      ITOT=3*(NROW+6)                                                   S1P01020
      WRITE OUTPUT TAPE 6,14, NROW, NCOL, XH, XK                        S1P01030
      WRITE OUTPUT TAPE 6, 15, ZNU, THC, PH1, FF, RH                    S1P01040
      DD = 1./(12.*RH*RH)                                               S1P01050
      IF (IOPT1) 23,23,22                                               S1P01060
   22 READ INPUT TAPE 5, 4, (MM(I), I=1,NROW)                           S1P01070
      MM(NR1)=MM(NROW)                                                  S1P01080
      WRITE OUTPUT TAPE 6, 919                                          S1P01090
      GO TO 25                                                          S1P01100
   23 DO 24 J=1, 30                                                     S1P01110
   24 MM(J)=0                                                           S1P01120
```

```
   25 IF (IOPT2) 31, 31, 26                                        S1P01130
   26 YK(0)=PH1*FF                                                 S1P01140
      ZETA(1) = PH1*FF                                             S1P01150
      X = ZETA(1) - XH/2.**MM(1)                                   S1P01160
      YK(1)=X                                                      S1P01170
      ZETA(2)=X                                                    S1P01180
      NDIM=3*NROW                                                  S1P01190
      MO=0                                                         S1P01200
      GO TO 35                                                     S1P01210
   31 YK(1)=PH1*(1.+FF)/2.                                         S1P01220
      X=YK(1)                                                      S1P01230
      ZETA (2)=X                                                   S1P01240
      NDIM=3*NROW-1                                                S1P01250
      WRITE OUTPUT TAPE 6, 922                                     S1P01260
      NCRV1=1                                                      S1P01270
      MO=1                                                         S1P01280
   35 WRITE OUTPUT TAPE 6, 920, (I, I=MO,NR1)                      S1P01290
      NR4=NR1+1-MO                                                 S1P01300
      DO 30 J=2, NROW                                              S1P01310
      IF (MM(J)-MM(J-1)) 27, 27, 28                                S1P01320
   27 JM=MM(J)                                                     S1P01330
      GO TO 29                                                     S1P01340
   28 JM=MM(J-1)                                                   S1P01350
   29 X=X-XH/2.**JM                                                S1P01360
      YK(J)=X                                                      S1P01370
      ZETA(J+1)=X                                                  S1P01380
   30 CONTINUE                                                     S1P01390
      YK(NR1)=PH1                                                  S1P01400
      ZETA (NR1+1)=PH1                                             S1P01410
      WRITE OUTPUT TAPE 6, 921, (YK(I), I=MO, NR1)                 S1P01420
      NSM=NDIM-NROW                                                S1P01430
      NSQ=72*NDIM                                                  S1P01440
      IF(IOPT4-1) 82, 106, 106                                     S1P01450
   82 WRITE OUTPUT TAPE 6, 925                                     S1P01460
      GO TO 84                                                     S1P01470
  106 READ INPUT TAPE 5, 2, TE, TI, TO, OC                         S1P01480
      WRITE OUTPUT TAPE 6, 951, TE, TI, TO, OC                     S1P01490
      TT1 = (TE + TI)/2. - TO                                      S1P01500
      TT2 = (TE -TI)                                               S1P01510
```

```
      TC = (1.+ ZNU)*OC*TT1                                             S1P01520
      TD = (1.+ZNU)*OC*TT2                                              S1P01530
   84 CONTINUE                                                          S1P01540
      READ INPUT TAPE 5, 4, (MM(I), I=31, 35)                           S1P01550
   79 CONTINUE                                                          S1P01560
      CALL COEFZ                                                        S1P01570
      MFLAG=0                                                           S1P01580
      IF (KTIME) 81,81,400                                              S1P01590
   81 CONTINUE                                                          S1P01600
      REWIND KTAPE                                                      S1P01610
C     COMPUTE L, M,N AND  Z MATRICES OF FORWARD SWEEP                   S1P01620
  400 KTIME=KTIME+1                                                     S1P01630
      N1=NSM                                                            S1P01640
      N2=NSM                                                            S1P01650
      N3=NSM                                                            S1P01660
      I=1                                                               S1P01670
      GO TO 405                                                         S1P01680
  401 CALL WTAPE (XZTP,Z1,N1,1)                                         S1P01690
      CALL RTAPE (XMTP,TMP, NSQ, 0)                                     S1P01700
      CALL MTX (YK, I, 2)                                               S1P01710
      IF (I-2) 405, 403, 402                                            S1P01720
  402 CALL BACK (XNTP)                                                  S1P01730
      CALL ZERO (YL, NSQ)                                               S1P01740
      CALL RTAPE (XMTP, TMP, NSQ,1)                                     S1P01750
      CALL MTXS (TMP, YL, I, 1)                                         S1P01760
      CALL RTAPE (XMTP, TMP, NSQ,0)                                     S1P01770
      CALL ADDM (YK, YL, YK, -NSQ)                                      S1P01780
      CALL RTAPE (XNTP, YL, NSQ, 0)                                     S1P01790
  403 N1=NDIM                                                           S1P01800
      CALL RTAPE (XMTP, TMP, NSQ,1)                                     S1P01810
      CALL MATM  (YK, TMP, TMP,NDIM,N2, NDIM)                           S1P01820
      IF (I-2) 405, 405, 404                                            S1P01830
  404 CALL RTAPE (XNTP, YL, NSQ, 1)                                     S1P01840
      CALL MTXS (YL, TMP,I, 1)                                          S1P01850
  405 CALL MTX (YL, I, 3)                                               S1P01860
      IF (I-2) 408, 406, 406                                            S1P01870
  406 CALL ADDM (YL, TMP, YL,-NSQ)                                      S1P01880
      IF (I-NCOL) 407, 408, 408                                         S1P01890
  407 CALL RTAPE (XNTP, TMP, NSQ,0)                                     S1P01900
```

```
  408 CALL INVERT (YL, N1, ISING)                                        S1P01910
      IF (I-1) 414, 414, 410                                             S1P01920
  410 CALL MATM (YK, Z1, T2, NDIM, N2,1)                                 S1P01930
      IF (I-NCOL) 411, 421, 421                                          S1P01940
  411 CALL  RTAPE (XNTP, TMP, NSQ, 1)                                    S1P01950
      CALL  MATM (YK, TMP,TMP,NDIM, N2, NDIM)                            S1P01960
  414 CALL  MTX (YK, I, 4)                                               S1P01970
      IF (I-2) 417, 416, 416                                             S1P01980
  416 CALL ADDM (YK, TMP, YK, -NSQ)                                      S1P01990
  417 IF (I-NCOL+1) 418, 419, 419                                        S1P02000
  418 CALL ZERO (TMP,NSQ)                                                S1P02010
       CALL MTXS (YL, TMP, I, 5)                                         S1P02020
      CALL WTAPE (XNTP, TMP, NSQ,0)                                      S1P02030
  419 CALL MATM (YL, YK, YK, N1, N1, NDIM)                               S1P02040
      CALL WTAPE (XMTP, YK, NSQ, 0)                                      S1P02050
      IF (I-NCOL+1) 420, 421, 421                                        S1P02060
  420 CALL WTAPE (XNTP, TMP, NSQ, 1)                                     S1P02070
      CALL BACK (XNTP)                                                   S1P02080
  421 CALL CONS(T1,I)                                                    S1P02090
      IF (I-1) 426, 426, 422                                             S1P02100
  422 CALL ADDM (T1, T2, T1, -NDIM)                                      S1P02110
      IF (I-2) 426, 424, 423                                             S1P02120
  423 CALL MTXS (Z2, T2, I,-1)                                           S1P02130
  424 DO 425 J=1,NDIM                                                    S1P02140
  425 Z2(J)=Z1(J)                                                        S1P02150
      IF (I-NCOL) 426, 428, 428                                          S1P02160
  426 CALL WTAPE (XMTP, YK, NSQ, 1)                                      S1P02170
      CALL BACK (XMTP)                                                   S1P02180
      IF (I-2) 430, 429, 428                                             S1P02190
  428 CALL ADDM (T1, T2, T1,-NDIM)                                       S1P02200
  429 CALL BACK (XMTP)                                                   S1P02210
  430 CALL MATM (YL, T1, Z1, N1, N1, 1)                                  S1P02220
      CALL WTAPE (XZTP, Z1, N1, 0)                                       S1P02230
      IF (I-NCOL) 431, 450, 450                                          S1P02240
  431 IF (I-2) 434,433,432                                               S1P02250
  432 N3=NDIM                                                            S1P02260
  433 N2=NDIM                                                            S1P02270
  434 I=I+1                                                              S1P02280
      GO TO 401                                                          S1P02290
```

```
C      DECOMPOSITION COMPLETED .  BEGIN BACKWARD SWEEP.                S1P02300
  450   CALL WTAPE (XZTP, Z1, N1,1)                                    S1P02310
       CALL BACK (XZTP)                                                S1P02320
       CALL BACK (XNTP)                                                S1P02330
       N4= (NCOL+3)*(NROW+6)*3                                         S1P02340
       CALL ZERO (TMP,N4)                                              S1P02350
  451 IF (I-NCOL) 452,454,454                                          S1P02360
  452 DO 453 J=1,NDIM                                                  S1P02370
       XX1(J)=XX(J)                                                    S1P02380
  453 XX(J)= Z1(J)                                                     S1P02390
       CALL RTAPE (XMTP, YK, NSQ, 1)                                   S1P02400
       CALL BACK (XMTP)                                                S1P02410
       IF (I-1) 454, 454, 4541                                         S1P02420
 4541 CALL BACK (XMTP).                                                S1P02430
  454 CALL RTAPE (XZTP, Z1, N1, 0)                                     S1P02440
       CALL RTAPE (XZTP, Z1, N1, 1)                                    S1P02450
       IF (I-1) 4543, 4543, 4542                                       S1P02460
 4542 CALL BACK (XZTP)                                                 S1P02470
 4543 CALL BACK (XZTP)                                                 S1P02480
       IF (I-NCOL+1) 456,457,462                                       S1P02490
  456 CALL RTAPE (XNTP, YL, NSQ, 0)                                    S1P02500
  457 CALL MATM( YK, XX, T1, N1, NDIM, 1)                              S1P02510
       CALL ADDM (Z1, T1, Z1, -NDIM)                                   S1P02520
       IF (I-NCOL+1) 458,462,462                                       S1P02530
  458 CALL RTAPE (XNTP, YL, NSQ, 1)                                    S1P02540
       IF (I-1) 4591, 4591, 459                                        S1P02550
  459 CALL BACK (XNTP)                                                 S1P02560
 4591 CALL BACK (XNTP)                                                 S1P02570
       CALL MATM (YL, XX1, T1, N1, NDIM, 1)                            S1P02580
       CALL ADDM (Z1, T1, Z1, -NDIM)                                   S1P02590
  460 IF (I-2) 463,461,462                                             S1P02600
  461 N1=NSM                                                           S1P02610
  462   CALL RTAPE (XMTP, YK, NSQ, 0)                                  S1P02620
  463 CALL STORE (Z1, I)                                               S1P02630
       IF (I-2) 500, 464, 464                                          S1P02640
  464 I=I-1                                                            S1P02650
       GO TO 452                                                       S1P02660
  500 MFLAG=1                                                          S1P02670
       IF (IOPT2) 145, 145, 140                                        S1P02680
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  140 L0=6                                                          S1P02690
      DO 141 L=1, NCOL                                              S1P02700
      TMP(L0)=TMP(L0+6)                                             S1P02710
  141 L0=L0+ITOT                                                    S1P02720
      L1=L0-ITOT                                                    S1P02730
      L0=L0+ITOT                                                    S1P02740
      TMP(L0)=TMP(L1)                                               S1P02750
  145 L0=NC1*ITOT+12                                                S1P02760
      DO 147 J=1, NROW                                              S1P02770
      L1=L0-2*ITOT                                                  S1P02780
      TMP(L0)=TMP(L1)                                               S1P02790
  147 L0=L0+3                                                       S1P02800
      L0=L0+3                                                       S1P02810
      TMP(L0)=TMP(L1)                                               S1P02820
      L0=L0-ITOT                                                    S1P02830
      DO 148 II=1, NCOL                                             S1P02840
      L0=L0-ITOT                                                    S1P02850
      TMP(L0)=TMP(L1)                                               S1P02860
  148 L1=L1-ITOT                                                    S1P02870
      CALL BOUND                                                    S1P02880
      IOUT=51                                                       S1P02890
      NC2=NCOL+3                                                    S1P02900
      IF (IOPT2) 501,501, 502                                       S1P02910
  501 NR2=NROW+3                                                    S1P02920
      GO TO 503                                                     S1P02930
  502 NR2=NROW+6                                                    S1P02940
  503 DO 520 I=1, NC2                                               S1P02950
      I3=I*(NROW+6)*3                                               S1P02960
      I2=I3-1                                                       S1P02970
      I1=I2-1                                                       S1P02980
      IF (IOUT+NR2-50) 505, 505, 504                                S1P02990
  504 WRITE OUTPUT TAPE 6, 1                                        S1P03000
      WRITE OUTPUT TAPE 6, 17                                       S1P03010
      IOUT=6                                                        S1P03020
  505 DO 515 JJ=1, NR2                                              S1P03030
      J=NROW-JJ+4                                                   S1P03040
      IF (J-NR1) 506, 511, 510                                      S1P03050
  506 IF (IOPT2) 507,507, 508                                       S1P03060
  507 IF (J-1) 512, 512, 510                                        S1P03070
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  508 IF (J) 510, 511, 510                                          S1P03080
  510 WRITE OUTPUT TAPE 6, 930, I, J, TMP(I1), TMP(I2), TMP(I3)     S1P03090
      GO TO 514                                                     S1P03100
  511 WRITE OUTPUT TAPE 6, 931, I, J, TMP(I1), TMP(I2), TMP(I3)     S1P03110
      GO TO 514                                                     S1P03120
  512 WRITE OUTPUT TAPE 6, 932, I, J, TMP(I1), TMP(I2), TMP(I3)     S1P03130
  514 I1=I1-3                                                       S1P03140
      I2=I2-3                                                       S1P03150
      I3=I3-3                                                       S1P03160
  515 IOUT=IOUT+1                                                   S1P03170
  520 CONTINUE                                                      S1P03180
  521 ISW3=1                                                        S1P03190
      IOUT=50                                                       S1P03200
      L=32                                                          S1P03210
      K=0                                                           S1P03220
      DO 540 J=MO, NR1                                              S1P03230
      IF (IOPT1) 537,537,536                                        S1P03240
  536 CALL GRADE (J)                                                S1P03250
  537 IF (MM(31)) 5378, 5378, 5370                                  S1P03260
 5370 IF (MM(L)-J) 5378, 5372, 5378                                 S1P03270
 5372 IF (L-35) 5374, 5374, 5378                                    S1P03280
 5374 L=L+1                                                         S1P03290
      K=K+1                                                         S1P03300
      K1=K                                                          S1P03310
      GO TO 5380                                                    S1P03320
 5378 K1=0                                                          S1P03330
 5380 DO 540 I=1, NC1                                               S1P03340
      IF (IOUT-41) 539, 538, 538                                    S1P03350
  538 WRITE OUTPUT TAPE 6, 1, RECORD                                S1P03360
      IOUT=0                                                        S1P03370
      IF (MFLAG) 532, 530, 531                                      S1P03380
  531 WRITE OUTPUT TAPE 6, 20                                       S1P03390
      WRITE OUTPUT TAPE 6, 18                                       S1P03400
      GO TO 539                                                     S1P03410
  530 WRITE OUTPUT TAPE 6, 20                                       S1P03420
      WRITE OUTPUT TAPE 6, 962                                      S1P03430
      GO TO 539                                                     S1P03440
  532 WRITE OUTPUT TAPE 6, 939                                      S1P03450
      WRITE OUTPUT TAPE 6, 19                                       S1P03460
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  539 IOUT=IOUT+1                                                    S1P03470
      CALL STRESS (I,J,K1)                                           S1P03480
  540 CONTINUE                                                       S1P03490
      IF (MFLAG) 999, 544, 541                                       S1P03500
  541 MFLAG=0                                                        S1P03510
      GO TO 521                                                      S1P03520
  544 WRITE OUTPUT TAPE 6, 1, RECORD                                 S1P03530
      I0=0                                                           S1P03540
      I1=1                                                           S1P03550
      I2=4                                                           S1P03560
      WRITE OUTPUT TAPE 6, 936                                       S1P03570
      I=1                                                            S1P03580
      DO 560 JJ=1, NR1                                               S1P03590
      J=NR1+1-JJ                                                     S1P03600
  550 WRITE OUTPUT TAPE 6, 937, J, I, (YK(I3), I3=I1, I2)            S1P03610
      I1=I1+4                                                        S1P03620
      I2=I1+3                                                        S1P03630
      IF (I-NCOL) 551, 552, 560                                      S1P03640
  551 I=I+1                                                          S1P03650
      GO TO 550                                                      S1P03660
  552 I=NC1                                                          S1P03670
      WRITE OUTPUT TAPE 6, 937, J, NC1, (YK(I3), I3=I1, I2)          S1P03680
      K1=8*(NC1+NR1)-3                                               S1P03690
      WRITE OUTPUT TAPE 6, 938, J, NC1, YK(K1)                       S1P03700
      I1=I1+4                                                        S1P03710
      I2=I1+3                                                        S1P03720
      GO TO 550                                                      S1P03730
  560 CONTINUE                                                       S1P03740
      IF (IOPT2) 566, 566, 562                                       S1P03750
  562 WRITE OUTPUT TAPE 6, 937, I0, NC1,(YK(I3), I3=I1, I2)          S1P03760
      K1=K1+4                                                        S1P03770
      WRITE OUTPUT TAPE 6, 938, I0, NC1, YK(K1)                      S1P03780
      I1=I1+4                                                        S1P03790
      I2=I1+3                                                        S1P03800
      IF (IOPT2) 566, 566, 564                                       S1P03810
  564 CONTINUE                                                       S1P03820
      DO 565 II=1, NC1                                               S1P03830
      I=NC1+1-II                                                     S1P03840
      WRITE OUTPUT TAPE 6, 937, I0, I, (YK(I3), I3=I1, I2)           S1P03850
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      I1=I1+4                                                           S1P03860
      I2=I1+3                                                           S1P03870
  565 CONTINUE                                                          S1P03880
  566 IF(IOPT3) 999,999,545                                             S1P03890
  545 MFLAG=-1                                                          S1P03900
      XM=0.                                                             S1P03910
      GO TO 521                                                         S1P03920
  999 CONTINUE                                                          S1P03930
   80 CALL CLOCK (TIM2)                                                 S1P03940
      TIME=TIM2-TIM1                                                    S1P03950
      TIM1=TIM2                                                         S1P03960
      PRINT 945, KTIME, TIME                                            S1P03970
      WRITE OUTPUT TAPE 6, 945, KTIME, TIME                             S1P03980
      IF (MM(31)) 1000, 1000, 601                                       S1P03990
  601 CALL CHAIN (2, 2)                                                 S1P04000
 1000 CALL RESET                                                        S1P04010
      GO TO 21                                                          S1P04020
      END                                                               S1P04030
*     FORTRAN                                                           S1P04040
      SUBROUTINE ADDM (X, Y, Z, M)                                      S1P04050
      DIMENSION X(3600), Y(3600), Z(3600)                               S1P04060
      IF (M) 20,1,1                                                     S1P04070
    1 DO 10 I=1,M                                                       S1P04080
   10 Z(I)= X(I)+Y(I)                                                   S1P04090
   11 GO TO 50                                                          S1P04100
   20 M=-M                                                              S1P04110
      DO 25 I=1,M                                                       S1P04120
   25 Z(I)= X(I)-Y(I)                                                   S1P04130
   50 RETURN                                                            S1P04140
      END                                                               S1P04150
*     FORTRAN                                                           S1P04160
      SUBROUTINE BOUND                                                  S1P04170
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P04180
      COMMON NCF                                                        S1P04190
      COMMON NDIM, NROW,NCOL,MM,I1,KM1,KM2,KP1,KP2,MFLAG,XM,XLD         S1P04200
      COMMON ISW1, ISW2, ISW3                                           S1P04210
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12       S1P04220
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10                 S1P04230
      COMMON C, C1, C2, C3, C4, C5, C6, C7, C8,C9, C10,C11,C12,C13,C14, S1P04240
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1    C15, C16, C17, C18, C19                                            S1P04250
     COMMON FILL                                                        S1P04260
     COMMON TMP, YK, YL                                                 S1P04270
     DIMENSION FILL(1188)                                               S1P04280
     DIMENSION TMP (5184), YK(5184), YL(5184)                           S1P04290
     DIMENSION MM(35)                                                   S1P04300
     DIMENSION NN(3)                                                    S1P04310
     I1=0                                                               S1P04320
     NR1=NROW+1                                                         S1P04330
     NC1=NCOL+1                                                         S1P04340
     L=0                                                                S1P04350
     ITOT=3*(NROW+6)                                                    S1P04360
     L1=ITOT                                                            S1P04370
     CALL GRADE(1)                                                      S1P04380
     LL=KP2                                                             S1P04390
     CALL GRADE(NROW)                                                   S1P04400
     LL2=KM2                                                            S1P04410
     DO 460 I=1, NCOL                                                   S1P04420
     TP=TMP(L+15)                                                       S1P04430
     TP2=TMP(L1-12)                                                     S1P04440
     N1=L1                                                              S1P04450
     DO 458 K=3,5                                                       S1P04460
     N=K+L                                                              S1P04470
     CALL EXTRA (TMP( N), TMP( N+3), TMP( N+6), TMP( N+9),  TP)         S1P04480
     CALL EXTRA (TMP(N1), TMP(N1-3), TMP(N1-6), TMP(N1-9), TP2)         S1P04490
     N1=K+L1-8                                                          S1P04500
     TP =TMP(N+13)                                                      S1P04510
     TP2=TMP(N1-12)                                                     S1P04520
     IF (LL) 453, 454, 454                                              S1P04530
453  TP=(TP+TMP(N+10))*.5                                               S1P04540
454  IF (LL2) 458, 458, 456                                             S1P04550
456  TP2=(TP2+TMP(N1-9))*.5                                             S1P04560
458  CONTINUE                                                           S1P04570
     L=L+ITOT                                                           S1P04580
     L1=L1+ITOT                                                         S1P04590
460  CONTINUE                                                           S1P04600
     NN(1)=NC1*ITOT+7                                                   S1P04610
     NN(2)=NN(1)+1                                                      S1P04620
     NN(3)=NN(2)+ITOT+1                                                 S1P04630
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      DO 515 J=1, NROW                                                  S1P04640
      DO 510 K=1, 3                                                     S1P04650
      N=NN(K)+3*J                                                       S1P04660
      N1=N-ITOT                                                         S1P04670
      N2=N1-ITOT                                                        S1P04680
      N3=N2-ITOT                                                        S1P04690
      N4=N3-ITOT                                                        S1P04700
      CALL EXTRA (TMP(N), TMP(N1), TMP(N2), TMP(N3), TMP(N4))           S1P04710
  510 CONTINUE                                                          S1P04720
  515 CONTINUE                                                          S1P04730
      L=NC1*ITOT                                                        S1P04740
      L1=L+4                                                            S1P04750
      LL=L1-2*ITOT                                                      S1P04760
      TMP(L1)=(TMP(LL)+TMP(L1+6))/2.                                    S1P04770
      TMP(L1+1)=(TMP(LL+1)+TMP(L1+7))/2.                                S1P04780
      L1=L+ITOT-5                                                       S1P04790
      LL=L1-2*ITOT                                                      S1P04800
      TMP(L1)=(TMP(LL)+TMP(L1-6))/2.                                    S1P04810
      TMP(L1+1)=(TMP(LL+1)+TMP(L1-5))/2.                                S1P04820
      RETURN                                                            S1P04830
      END                                                               S1P04840
*     FORTRAN                                                           S1P04850
*     LIST                                                              S1P04860
      SUBROUTINE CF(I, J, MF, K, AA, X)                                 S1P04870
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P04880
      COMMON NCF                                                        S1P04890
      COMMON NDIM, NROW,NCOL,MM,I1,KM1,KM2,KP1,KP2,MFLAG,XM,XLD         S1P04900
      COMMON ISW1, ISW2, ISW3                                           S1P04910
      COMMON A                                                          S1P04920
      COMMON TMP, YK, YL                                                S1P04930
      DIMENSION MM(35)                                                  S1P04940
      DIMENSION A(1232)                                                 S1P04950
      DIMENSION AA(1)                                                   S1P04960
      DIMENSION X(72, 72)                                               S1P04970
      DIMENSION TMP (5184), YK(5184), YL(5184)                          S1P04980
C     COMPUTE COEFFICIENT OF KTH UNKNOWN FOR MESH PT I,J.               S1P04990
      I2=I                                                              S1P05000
      J2=J                                                              S1P05010
      M=MF                                                              S1P05020
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      J4 = ISW1*NCF+1                                                   S1P05030
      NC1=NCOL+1                                                        S1P05040
      NR1=NROW+1                                                        S1P05050
      IF (ISW2) 107, 108, 106                                           S1P05060
  106 J4=1                                                              S1P05070
      GO TO 108                                                         S1P05080
  107 FCTR=-1.                                                          S1P05090
      GO TO 109                                                         S1P05100
  108 FCTR=1.                                                           S1P05110
  109 IF (M) 110, 100, 120                                              S1P05120
  110 IF (M+1) 111, 112, 112                                            S1P05130
  111 J2=J2-1                                                           S1P05140
      M=0                                                               S1P05150
      GO TO 100                                                         S1P05160
  112 FCTR=FCTR/2.                                                      S1P05170
      J5=J2-1                                                           S1P05180
      GO TO 101                                                         S1P05190
  120 IF (M-1) 122, 122, 121                                            S1P05200
  121 J2=J2+1                                                           S1P05210
      M=0                                                               S1P05220
      GO TO 100                                                         S1P05230
  122 FCTR=FCTR/2.                                                      S1P05240
      J5=J2+1                                                           S1P05250
  100 CONTINUE                                                          S1P05260
  101 IF (I2-1) 2, 4, 6                                                 S1P05270
C     COL I2 IS LEFT OF X-AXIS. REFLECT OVER SYMMETRY LINE. CHANGE SIGN S1P05280
C     IF K=2                                                            S1P05290
    2 I2=-I2+2                                                          S1P05300
      IF (K-2) 6, 3, 6                                                  S1P05310
    3 FCTR=-FCTR                                                        S1P05320
      GO TO 6                                                           S1P05330
C     COL I2 IS X-AXIS. OMIT COEFFICIENT IF K=2                         S1P05340
    4 IF (K-2) 6, 99, 6                                                 S1P05350
    6 IF (J2-NR1) 14, 99, 7                                             S1P05360
    7 IF (J2-NR1-1) 8, 8, 11                                            S1P05370
    8 IF (K-2) 11, 11, 9                                                S1P05380
    9 IF (I2-NC1) 10, 99, 11                                            S1P05390
C    COL J2 IS BEYOND THE BOUNDARY. K=3. SET J2=NROW-1                  S1P05400
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 10 J2=J2-2                                                  S1P05410
    GO TO 50                                                 S1P05420
 11 J2=NR1                                                   S1P05430
 12 IF (I2-NC1) 80, 99, 13                                   S1P05440
 13 I2=NC1                                                   S1P05450
    GO TO 80                                                 S1P05460
 14 IF (IOPT2) 15, 15, 19                                    S1P05470
 15 IF (J2-1) 16, 18, 25                                     S1P05480
 16 J2=-J2+2                                                 S1P05490
    IF (K-1) 17, 17, 25                                      S1P05500
 17 FCTR=-FCTR                                               S1P05510
    GO TO 25                                                 S1P05520
 18 IF (K-1) 99, 99, 25                                      S1P05530
 19 IF (J2) 20, 99, 25                                       S1P05540
 20 IF (J2+1) 24, 21, 21                                     S1P05550
 21 IF (K-2) 24, 24, 22                                      S1P05560
 22 IF (I2-NC1) 23, 99, 24                                   S1P05570
 23 J2=1                                                     S1P05580
    GO TO 50                                                 S1P05590
 24 J2=0                                                     S1P05600
    GO TO 12                                                 S1P05610
 25 IF (I2-NC1) 50, 99, 26                                   S1P05620
 26 IF (I2-NC1-1) 27, 27, 13                                 S1P05630
 27 IF (K-2) 13, 13, 28                                      S1P05640
 28 I2=I2-2                                                  S1P05650
 50 J1=INDX(I2, J2, K)                                       S1P05660
    IF (MFLAG) 51, 51, 52                                    S1P05670
 51 X(I1, J1)=X(I1, J1)+AA(J4)*FCTR                          S1P05680
125 IF (M) 130, 99, 130                                      S1P05690
 52 YK(I1+2970)=YK(I1+2970)-AA(J4)*FCTR*TMP(J1)              S1P05700
    GO TO 125                                                S1P05710
 80 J1=INDX(I2, J2, K)                                       S1P05720
    J3=(J1+5-I1)*270+I1                                      S1P05730
    YK(J3)=YK(J3)+AA(J4)*FCTR                                S1P05740
    IF (M) 135, 99, 135                                      S1P05750
 99 RETURN                                                   S1P05760
130 J2=J5                                                    S1P05770
    M=0                                                      S1P05780
    GO TO 50                                                 S1P05790
135 J2=J5                                                    S1P05800
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      M=0                                                               S1P05810
      GO TO 80                                                          S1P05820
      END                                                               S1P05830
*     FORTRAN                                                           S1P05840
      FUNCTION CFZ( J, AA)                                              S1P05850
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P05860
      COMMON NCF                                                        S1P05870
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                        S1P05880
      DIMENSION MM(40), AA(1)                                           S1P05890
      J1 = J*NCF+1                                                      S1P05900
      CFZ=AA(J1)                                                        S1P05910
      RETURN                                                            S1P05920
      END                                                               S1P05930
*     FORTRAN                                                           S1P05940
      SUBROUTINE COEFZ                                                  S1P05950
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P05960
      COMMON NCF                                                        S1P05970
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                        S1P05980
      COMMON ISW1, ISW2, ISW3                                           S1P05990
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8 ,A9,A10,A11, A12         S1P06000
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10                 S1P06010
      COMMON C, C1, C2, C3, C4, C5, C6, C7, C8,C9, C10,C11,C12,C13,C14, S1P06020
     1 C15, C16, C17 ,C18,C19                                           S1P06030
      COMMON FILL                                                       S1P06040
      COMMON  TMP, YK, YL                                               S1P06050
      COMMON T1, T2, XX, XX1, Z, Z1, Z2                                 S1P06060
      COMMON ZNU, THC, PH1, FF, RH, DD,XXH, XK                          S1P06070
      DIMENSION TMP (5184), YK(5184), YL(5184)                          S1P06080
      DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89) S1P06090
      DIMENSION MM(40)                                                  S1P06100
      DIMENSION A(1)                                                    S1P06110
      DIMENSION FILL (1188)                                             S1P06120
      NR1=NROW+1                                                        S1P06130
      D1 = (1.-ZNU)                                                     S1P06140
      D2 = (1. +ZNU)                                                    S1P06150
      D3 = (1.+DD)                                                      S1P06160
      D4 = (1.+4.*DD)                                                   S1P06170
      D5 = (2.-ZNU)                                                     S1P06180
      D6 = (3.-ZNU)                                                     S1P06190
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      D7 = (3.-2.*ZNU)                                          S1P06200
      YA5 = D2/2. + D5*DD                                       S1P06210
      YA66 = D6/2. + D7*DD                                      S1P06220
      YB10 = D2 -2.*D1*DD                                       S1P06230
      DO 60 JJ = 0,NR1                                          S1P06240
      J = NR1 -JJ                                               S1P06250
      IF(J) 55,55, 54                                           S1P06260
   54 XH = XXH/(2.**MM(J))                                      S1P06270
   55 X = YK(J)                                                 S1P06280
      SX = SINF(X)                                              S1P06290
      CX = COSF(X)                                              S1P06300
      YA1 = D3 *SX                                              S1P06310
      YA2 = D1*D4/(2.*SX)                                       S1P06320
      YA3 = D3*CX                                               S1P06330
      YA4 = -D3*(CX*CX + ZNU*SX*SX)/SX                          S1P06340
      YA6 = -YA66*CX/SX                                         S1P06350
      YA7 = -DD*SX                                              S1P06360
      YA8 = -D5*DD/SX                                           S1P06370
      YA9 = -DD*CX                                              S1P06380
      YA10 = D6*DD*CX/(SX*SX)                                   S1P06390
      YA11 = (D2*SX - DD *YA4/D3)                               S1P06400
      YB3 = D1*D4*SX/2.                                         S1P06410
      YB4 = D3/SX                                               S1P06420
      YB5 = D1*D4*CX/2.                                         S1P06430
      YB6 = YA2*(2.*SX*SX- 1.)                                  S1P06440
      YB7 = -D5*DD                                              S1P06450
      YB8 = -DD/(SX*SX)                                         S1P06460
      YB9 = -DD*CX/SX                                           S1P06470
      YC2 = D5/SX                                               S1P06480
      YC3 = 2.*CX                                               S1P06490
      YC4 = CX/(SX*SX)                                          S1P06500
      YC5 = -((1.+ZNU*SX*SX)/SX + D2*SX/DD)                     S1P06510
      YC6 = (D1-D2/DD + 1./(SX*SX))*CX                          S1P06520
      YC8 = 1./(SX*SX)                                          S1P06530
      YC9 = -CX/SX                                              S1P06540
      YC10 = (2.*D1 -D2/DD+ YC8)                                S1P06550
      YC12 = -2./SX                                             S1P06560
      YC13 = -YC8/SX                                            S1P06570
      YC15 = 2.*CX*YC8                                          S1P06580
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      YC16 = (1.+ZNU*SX*SX)/SX                                          S1P06590
      YC17 = 4.*YC13 + D2/SX                                            S1P06600
      YC18 = -(D1+YC8)*CX                                               S1P06610
      YC19 = -2.*D2*SX/DD                                               S1P06620
      XHH = XH*XH                                                       S1P06630
      XHHH = XHH*XH                                                     S1P06640
      XHHHH = XHHH*XH                                                   S1P06650
      XKK = XK*XK                                                       S1P06660
      XKKK = XKK*XK                                                     S1P06670
      XKKKK = XKKK*XK                                                   S1P06680
      A1 = YA1/XHH + YA3/(2.*XH)                                        S1P06690
      A2 = YA1/XHH - YA3/(2.*XH)                                        S1P06700
      A3 = YA2/XKK                                                      S1P06710
      A4 = -(A1 +A2)-2.*A3 + YA4                                        S1P06720
      A5 = YA5/(4.*XH*XK)                                               S1P06730
      A6 = YA6/(2.*XK   )                                               S1P06740
      A7 = YA7/(2.*XHHH)                                                S1P06750
      A10 = YA10/XKK                                                    S1P06760
      A11 = YA8/(2.*XH*XKK)                                             S1P06770
      A13 = YA9/XHH                                                     S1P06780
      A14 = YA11/(2.*XH)                                                S1P06790
      A8 = -2.*A7 -2.*A11 + A13 + A14                                   S1P06800
      A9 = +2.*A7 +2.*A11 + A13 - A14                                   S1P06810
      A12 = -2.* A13 -2. *A10                                           S1P06820
      B1 = YA5/(4.*XH*XK)                                               S1P06830
      B2 = -YA6/(2.*XK)                                                 S1P06840
      B3 = YB3/XHH + YB5/(2.*XH)                                        S1P06850
      B4 = YB3/XHH - YB5/(2.*XH)                                        S1P06860
      B5 = YB4/XKK                                                      S1P06870
      B6 = -B3-B4-2.*B5 + YB6                                           S1P06880
      B7 =-YB7/(   2.*XHH*XK) -YB8/XKKK + YB10/(2.*XK)                  S1P06890
      B8 = YB7/(   2.*XHH*XK) + YB9/(4.*XH*XK)                          S1P06900
      B9=YB7/(2.*XHH*XK)-YB9/(4.*XH*XK)                                 S1P06910
      B10 = YB8/(2.*XKKK)                                               S1P06920
      C1 = SX/(2.*XHHH)                                                 S1P06930
      C4 = YC4/XKK                                                      S1P06940
      C5 = YC2/(2.*XH*XKK)                                              S1P06950
      C10= YC8/(2.*XKKK)                                                S1P06960
      C13 = YC13/XKKKK                                                  S1P06970
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      C2 = -2.*C1-2.*C5+YC3/XHH+YC5/(2.*XH)                            S1P06980
      C3 = +2.*C1+2.*C5+YC3/XHH-YC5/(2.*XH)                            S1P06990
      C6 = -2.*YC3/XHH -2.*C4+YC6                                      S1P07000
      C7=-D5/(XHH*XK)-2.*C10+YC10/(2.*XK)                              S1P07010
      C8 = D5 /(2.*XHH*XK) + YC9/(4.*XH*XK)                            S1P07020
      C9 = D5 /(2.*XHH*XK) - YC9/(4.*XH*XK)                            S1P07030
      C11 =      -SX/XHHHH - YC3/(2.*XHHH)                             S1P07040
      C12 =      -SX/XHHHH + YC3/(2.*XHHH)                             S1P07050
      C14 =  4.*SX/XHHHH -2.*YC12/    (XHH*XKK) + YC3/XHHH-YC15/(XH*XKK)S1P07060
     1 + YC16/(XHH) + YC18/(2.*XH)                                     S1P07070
      C15 = 4.*SX/XHHHH-2.YC12/(XHH*XKK) - YC3/XHHH + YC15/(XH*XKK)    S1P07080
     1 + YC16/XHH -YC18/(2.*XH)                                        S1P07090
      C16 = -2.*YC12/(XHH*XKK) -4.*YC13/XKKKK + YC17/XKK               S1P07100
      C17 = YC12/(XHH*XKK) + YC15/(2.*XH*XKK)                          S1P07110
      C18 = YC12/(XHH*XKK) -YC15/(2.*XH*XKK)                           S1P07120
       C19 = -6.*SX/XHHHH + 4.*YC12/(XHH*XKK) +6.*YC13/XKKKK           S1P07130
     1 -2.*YC16/XHH -2.*YC17 /XKK + YC19                               S1P07140
      A=1.                                                             S1P07150
      C=1.                                                             S1P07160
      CALL NORM(A1,A,12)                                               S1P07170
      CALL NORM(B1,B,10)                                               S1P07180
      CALL NORM(C1,C,19)                                               S1P07190
      DO 58 L =1,NCF                                                   S1P07200
      L1 = J*NCF+L                                                     S1P07210
   58 A(L1)=A(L)                                                       S1P07220
   60 CONTINUE                                                         S1P07230
      RETURN                                                           S1P07240
      END                                                              S1P07250
*     FORTRAN                                                          S1P07260
      SUBROUTINE CONS (X, I)                                           S1P07270
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8    S1P07280
      COMMON NCF                                                       S1P07290
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                       S1P07300
      COMMON ISW1, ISW2, ISW3                                          S1P07310
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12      S1P07320
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10                S1P07330
      COMMON C, C1, C2, C3, C4, C5, C6, C7, C8,C9, C10,C11,C12,C13,C14, S1P07340
     1   C15, C16, C17, C18, C19                                       S1P07350
      COMMON FILL                                                      S1P07360
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      COMMON   TMP, YK, YL                                               S1P07370
      COMMON T1, T2, XX, XX1, Z, Z1, Z2                                  S1P07380
      COMMON ZNU, THC, PH1, FF, RH, DD, XH, XK                           S1P07390
      COMMON ZETA                                                        S1P07400
      COMMON TE, TI, TO, OC, TC, TD, DDLD                                S1P07410
      DIMENSION TMP (5184), YK(5184), YL(5184)                           S1P07420
      DIMENSION ZETA (30)                                                S1P07430
      DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89) S1P07440
      DIMENSION MM(40)                                                   S1P07450
      DIMENSION X(72), A(1), B(1), C(1)                                  S1P07460
      DIMENSION FILL(1188)                                               S1P07470
    3 DO 5 J=1, NDIM                                                     S1P07480
    5 X(J)=0.                                                            S1P07490
      IF (IOPT4-1) 6, 21, 21                                             S1P07500
    6 DO 10 J=1, NROW                                                    S1P07510
      I1=INDX (I, J, 3)                                                  S1P07520
      J4 = J*NCF+1                                                       S1P07530
   10 X(I1) = C(J4) * (ZNU**2-1.) * SINF(ZETA(J+1)) / DD                 S1P07540
      GO TO 99                                                           S1P07550
   21 CONTINUE                                                           S1P07560
      DO 31 J = 1, NROW                                                  S1P07570
      J4 = J*NCF+1                                                       S1P07580
      I1 =  INDX(I,J,3)                                                  S1P07590
      X(I1) = C(J4) * SINF(ZETA(J+1)) * TC / DD                          S1P07600
   31 CONTINUE                                                           S1P07610
   99 RETURN                                                             S1P07620
      END                                                                S1P07630
*     FORTRAN                                                            S1P07640
      FUNCTION DFF (II, JJ, KK, MF)                                      S1P07650
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8      S1P07660
      COMMON NCF                                                         S1P07670
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                         S1P07680
      COMMON ISW1, ISW2, ISW3                                            S1P07690
      COMMON A                                                           S1P07700
      COMMON   TMP, YK, YL                                               S1P07710
      DIMENSION  MM(40)                                                  S1P07720
      DIMENSION A(1232)                                                  S1P07730
      DIMENSION TMP (5184), YK(5184), YL(5184)                           S1P07740
      N2=3*(NROW+6)                                                      S1P07750
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      I=II                                                      S1P07760
      J=JJ                                                      S1P07770
      K=KK                                                      S1P07780
       M=MF                                                     S1P07790
      IF (M) 60, 50, 70                                         S1P07800
   60 IF (M+1) 61, 62, 62                                       S1P07810
   61 J=J-1                                                     S1P07820
      M=0                                                       S1P07830
      GO TO 50                                                  S1P07840
   62 J2=J-1                                                    S1P07850
      GO TO 50                                                  S1P07860
   70 IF (M-1) 72, 72, 71                                       S1P07870
   71 J=J+1                                                     S1P07880
      M=0                                                       S1P07890
      GO TO 50                                                  S1P07900
   72 J2=J+1                                                    S1P07910
   50 SIGN=1.                                                   S1P07920
      IF (I-1) 1, 3, 3                                          S1P07930
    1 I=2-I                                                     S1P07940
      IF (K-2) 3, 2, 3                                          S1P07950
    2 SIGN=-1.                                                  S1P07960
      GO TO 5                                                   S1P07970
    3 IF (J-1) 4, 5, 5                                          S1P07980
    4 IF (IOPT2) 6, 6, 5                                        S1P07990
    6 J=2-J                                                     S1P08000
      IF (K-1) 2, 2, 5                                          S1P08010
    5 I2=(I-1)*N2+3*J+K+6                                       S1P08020
      IF (M) 16, 13, 16                                         S1P08030
   13 IF (SIGN) 14, 15, 15                                      S1P08040
   14 DEF=-TMP(I2)                                              S1P08050
      GO TO 99                                                  S1P08060
   15 DEF=TMP(I2)                                               S1P08070
      GO TO 99                                                  S1P08080
   16 I3=(I-1)*N2+3*J2+K+6                                      S1P08090
      DEF=SIGN*(TMP(I2)+TMP(I3))/2.                             S1P08100
                                                                S1P08110
   99 RETURN                                                    S1P08120
      END                                                       S1P08130
*     FORTRAN                                                   S1P08140
      SUBROUTINE EQ1 (X, III, II, JJ, MX)
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C     COMPUTE COEFFICIENTS FOR EQUATION ONE FOR MESH PT I,J              S1P08150
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8      S1P08160
      COMMON NCF                                                         S1P08170
      COMMON NDIM, NROW,NCOL,MM,KO,KM1,KM2,KP1,KP2,MFLAG,XM,XLD          S1P08180
      COMMON ISW1, ISW2, ISW3                                            S1P08190
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12        S1P08200
      DIMENSION MM(35)                                                   S1P08210
      I1=II1                                                             S1P08220
      I=II                                                               S1P08230
      J=JJ                                                               S1P08240
      M=MX                                                               S1P08250
      GO TO (30, 20, 30, 40, 50), M                                      S1P08260
   20 CONTINUE                                                           S1P08270
      MF=0                                                               S1P08280
      ISW2=0                                                             S1P08290
      CALL CF (I-1, J, MF, 1, A3, X)                                     S1P08300
      CALLCF(I-1,J  ,MF,3,A10,X)                                         S1P08310
      ISW2=-1                                                            S1P08320
      CALL CF (I-1, J, MF,2, A6, X)                                      S1P08330
      MF=KM1                                                             S1P08340
      CALL CF (I-1, J-1, MF, 2, A5,X)                                    S1P08350
      ISW2=0                                                             S1P08360
      CALLCF(I-1,J-1,MF,3,A11,X)                                         S1P08370
      MF=KP1                                                             S1P08380
      CALL CF (I-1, J+1, MF, 2, A5,X)                                    S1P08390
      ISW2 = -1                                                          S1P08400
      CALLCF(I-1,J+1,MF,3,A11,X)                                         S1P08410
      GO TO 50                                                           S1P08420
   30 CONTINUE                                                           S1P08430
      ISW2=0                                                             S1P08440
      MF=0                                                               S1P08450
      CALL CF (I, J, MF, 1,  A4,X)                                       S1P08460
      CALLCF(I  ,J  ,MF,3,A12,X)                                         S1P08470
      MF=KM1                                                             S1P08480
      CALL CF (I, J-1, MF, 1, A1, X)                                     S1P08490
      CALLCF(I  ,J-1,MF,3,A8 ,X)                                         S1P08500
      MF=KP1                                                             S1P08510
      CALL CF (I, J+1, MF, 1, A2, X)                                     S1P08520
      CALLCF(I  ,J+1,MF,3,A9 ,X)                                         S1P08530
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      MF = KM2                                                          S1P08540
      CALLCF(I   ,J-2,MF,3,A7  ,X)                                      S1P08550
      MF = KP2                                                          S1P08560
      ISW2=-1                                                           S1P08570
      CALLCF(I   ,J+2,MF,3,A7  ,X)                                      S1P08580
      IF (MFLAG) 50, 50, 40                                             S1P08590
   40 CONTINUE                                                          S1P08600
      MF=0                                                              S1P08610
      ISW2=0                                                            S1P08620
      CALL CF (I+1, J, MF, 1, A3, X)                                    S1P08630
      CALL CF (I+1, J, MF,2, A6,X)                                      S1P08640
      CALLCF(I+1,J   ,MF,3,A10,X)                                       S1P08650
      MF=KM1                                                            S1P08660
      CALL CF (I+1, J-1, MF, 2, A5,X)                                   S1P08670
      CALLCF(I+1,J-1,MF,3,A11,X)                                        S1P08680
      MF=KP1                                                            S1P08690
      ISW2=-1                                                           S1P08700
      CALL CF (I+1, J+1, MF, 2, A5,X)                                   S1P08710
      CALLCF(I+1,J+1,MF,3,A11,X)                                        S1P08720
      ISW2 = 0                                                          S1P08730
   45 IF (I-1) 20, 20, 46                                               S1P08740
   46 IF (MFLAG) 50, 50, 20                                             S1P08750
   50 RETURN                                                            S1P08760
      END                                                               S1P08770
*     FORTRAN                                                           S1P08780
      SUBROUTINE EQ2 (X, II1, II, JJ, MX)                               S1P08790
C     COMPUTE EQUATION TWO FOR MESH PT I, J.                            S1P08800
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P08810
      COMMON NCF                                                        S1P08820
      COMMON NDIM, NROW,NCOL,MM,KO,KM1,KM2,KP1,KP2,MFLAG,XM,XLD         S1P08830
      COMMON ISW1, ISW2, ISW3                                           S1P08840
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12       S1P08850
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10                 S1P08860
      DIMENSION MM(35)                                                  S1P08870
      I1=II1                                                            S1P08880
      I=II                                                              S1P08890
       J=JJ                                                             S1P08900
      M=MX                                                              S1P08910
      GO TO (30, 20, 30, 40, 50), M                                     S1P08920
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   20 CONTINUE                                        S1P08930
      ISW2=0                                          S1P08940
      MF=0                                            S1P08950
      CALL CF ( I-1, J, MF, 2, B5, X)                 S1P08960
      ISW2=-1                                         S1P08970
      CALL CF ( I-1, J, MF, 1, B2, X)                 S1P08980
      CALL CF ( I-1, J, MF, 3,  B7, X)                S1P08990
      MF=KM1                                          S1P09000
      CALL CF ( I-1, J-1, MF, 1, B1, X)               S1P09010
      CALL CF ( I-1, J-1, MF, 3, B8, X)               S1P09020
      MF=KP1                                          S1P09030
      CALL CF ( I-1, J+1, MF, 3, B9, X)               S1P09040
      ISW2=0                                          S1P09050
      CALL CF ( I-1, J+1, MF, 1, B1, X)               S1P09060
      GO TO 50                                        S1P09070
   30 CONTINUE                                        S1P09080
      ISW2=0                                          S1P09090
      MF=KM1                                          S1P09100
      CALL CF ( I, J-1, MF, 2, B3, X)                 S1P09110
      MF=KP1                                          S1P09120
      CALL CF ( I, J+1, MF, 2, B4, X)                 S1P09130
      MF=0                                            S1P09140
      CALL CF ( I, J, MF, 2, B6, X)                   S1P09150
   33 IF (MFLAG) 34, 34, 35                           S1P09160
   34 IF (I-2) 50, 35, 36                             S1P09170
   35 CONTINUE                                        S1P09180
      ISW2=-1                                         S1P09190
      CALL CF ( I-2, J, MF, 3, B10, X)                S1P09200
      IF (MFLAG) 50, 50, 37                           S1P09210
   36 IF (I-NCOL) 50, 37, 37                          S1P09220
   37 CONTINUE                                        S1P09230
      ISW2=0                                          S1P09240
      CALL CF ( I+2, J, MF, 3, B10, X)                S1P09250
      IF (MFLAG) 50, 50, 40                           S1P09260
   40 CONTINUE                                        S1P09270
      ISW2=0                                          S1P09280
      MF=0                                            S1P09290
      CALL CF ( I+1, J, MF, 1, B2,X)                  S1P09300
      CALL CF ( I+1, J, MF, 2, B5, X)                 S1P09310
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      CALL CF ( I+1, J, MF, 3, B7, X)                                   S1P09320
      MF=KM1                                                            S1P09330
      CALL CF ( I+1, J-1, MF, 1, B1, X)                                 S1P09340
      CALL CF ( I+1, J-1, MF, 3, B8, X)                                 S1P09350
      MF=KP1                                                            S1P09360
      CALL CF ( I+1, J+1, MF, 3, B9, X)                                 S1P09370
      ISW2=-1                                                           S1P09380
      CALL CF ( I+1, J+1, MF, 1, B1, X)                                 S1P09390
   45 IF (I-1) 20, 20, 46                                               S1P09400
   46 IF (MFLAG) 50, 50, 20                                             S1P09410
   50 RETURN                                                            S1P09420
      END                                                               S1P09430
*     FORTRAN                                                           S1P09440
      SUBROUTINE EQ3 (X, III, II, JJ, MX)                               S1P09450
C     COMPUTE EQUATION THREE  FOR MESH PT I,J.                          S1P09460
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P09470
      COMMON NCF                                                        S1P09480
      COMMON NDIM, NROW,NCOL,MM,K0,KM1,KM2,KP1,KP2,MFLAG,XM,XLD         S1P09490
      COMMON ISW1, ISW2, ISW3                                           S1P09500
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12       S1P09510
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10                 S1P09520
      COMMON C, C1, C2, C3, C4, C5, C6, C7, C8,C9, C10,C11,C12,C13,C14, S1P09530
     1   C15, C16, C17, C18, C19                                        S1P09540
      DIMENSION MM(35)                                                  S1P09550
      I1=III                                                            S1P09560
      I=II                                                              S1P09570
       J=JJ                                                             S1P09580
      M=MX                                                              S1P09590
      GO TO (30, 20, 30, 40, 50), M                                     S1P09600
   20 CONTINUE                                                          S1P09610
      ISW2=0                                                            S1P09620
      MF=0                                                              S1P09630
      CALL CF(I-1,J  ,MF,1,C4 ,X)                                       S1P09640
      CALL CF(I-1,J  ,MF,3,C16,X)                                       S1P09650
      ISW2=-1                                                           S1P09660
      CALL CF(I-1,J  ,MF,2,C7 ,X)                                       S1P09670
      MF=KP1                                                            S1P09680
      CALL CF(I-1,J+1,MF,1,C5 ,X)                                       S1P09690
      CALL CF(I-1,J+1,MF,2,C9 ,X)                                       S1P09700
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      ISW2=0                                                            S1P09710
      CALL CF(I-1,J+1,MF,3,C18,X)                                       S1P09720
      MF=KM1                                                            S1P09730
      CALL CF(I-1,J-1,MF,1,C5 ,X)                                       S1P09740
      CALL CF(I-1,J-1,MF,3,C17,X)                                       S1P09750
      ISW2 = -1                                                         S1P09760
      CALL CF(I-1,J-1,MF,2,C8 ,X)                                       S1P09770
      IF (I-1) 21, 21, 22                                               S1P09780
   21 ISW2=1                                                            S1P09790
      CX=CFZ(J, C10)                                                    S1P09800
      CALL CF (I-1, J, 0;2, -4.*CX, X)                                  S1P09810
      GO TO 50                                                          S1P09820
   22 IF (I-NCOL) 50, 24, 24                                            S1P09830
   24 ISW2=1                                                            S1P09840
      CX=CFZ(J, C10)                                                    S1P09850
      CALL CF (I-1,  J, 0, 2, 4.*CX, X)                                 S1P09860
      GO TO 50                                                          S1P09870
   30 CONTINUF                                                          S1P09880
      ISW2=0                                                            S1P09890
      MF=KM1                                                            S1P09900
      CALL CF(I  ,J-1,MF,1,C2 ,X)                                       S1P09910
      CALL CF(I  ,J-1,MF,3,C14,X)                                       S1P09920
      MF=KP1                                                            S1P09930
      CALL CF(I  ,J+1,MF,1,C3 ,X)                                       S1P09940
      CALL CF(I  ,J+1,MF,3,C15,X)                                       S1P09950
      MF=KM2                                                            S1P09960
      CALL CF(I  ,J-2,MF,3,C11,X)                                       S1P09970
      ISW2=0                                                            S1P09980
      MF=KP2                                                            S1P09990
      CALL CF(I  ,J+2,MF,3,C12,X)                                       S1P10000
      MF=0                                                              S1P10010
      CALL CF(I  ,J  ,MF,1,C6 ,X)                                       S1P10020
      CALL CF(I  ,J  ,MF,3,C19,X)                                       S1P10030
      IF (J-NROW) 32, 31, 31                                            S1P10040
   31 ISW2=1                                                            S1P10050
      CX=CFZ(J,C1)                                                      S1P10060
      CALL CF(I, J+1,  KP1, 1, -4.*CX,X)                                S1P10070
      CALL CF (I,  J,  0, 1, 6.*CX, X)                                  S1P10080
      CALL CF(I, J-1, KM1, 1, -4.*CX,X)                                 S1P10090
```

```
      CALL CF (I, J-2, KM2, 1, 2.*CX, X)                                S1P10100
      GO TO 36                                                          S1P10110
   32 IF (J-1)  33, 33, 34                                              S1P10120
   33 ISW2=1                                                            S1P10130
      CX=CFZ(J,C1)                                                      S1P10140
      CALL CF(I, J-1, KM1, 1, 4.*CX, X)                                 S1P10150
      CALL CF(I, J, 0, 1, -6.*CX, X)                                    S1P10160
      CALL CF(I, J+1, KP1, 1, 4.*CX, X)                                 S1P10170
      CALL CF(I, J+2,KP2, 1, -2.*CX, X)                                 S1P10180
      GO TO 36                                                          S1P10190
   34 CONTINUE                                                          S1P10200
      CALL CF (I, J-2, KM2, 1, C1, X)                                   S1P10210
      ISW2=-1                                                           S1P10220
      CALL CF (I, J+2, KP2, 1,C1, X)                                    S1P10230
   36 IF (I-2) 360, 361, 362                                            S1P10240
  360 MP=MFLAG+1                                                        S1P10250
      GO TO 365                                                         S1P10260
  361 MP=MFLAG+3                                                        S1P10270
      GO TO 365                                                         S1P10280
  362 IF (I-NCOL) 363, 364, 364                                         S1P10290
  363 MP=MFLAG+5                                                        S1P10300
      GO TO 365                                                         S1P10310
  364 MP=MFLAG+7                                                        S1P10320
  365 GO TO (370, 366, 367, 366, 370, 366, 366, 366), MP                S1P10330
  366 CONTINUE                                                          S1P10340
      MF=0                                                              S1P10350
      ISW2 = 0                                                          S1P10360
      CALL CF(I+2,J  ,MF,3,C13,X)                                       S1P10370
      IF (MFLAG) 370, 370, 367                                          S1P10380
  367 CONTINUE                                                          S1P10390
      ISW2 = 0                                                          S1P10400
      CALL CF(I-2,J  ,MF,3,C13,X)                                       S1P10410
  370 GO TO (373, 372, 376, 375, 395, 375, 382, 380), MP                S1P10420
  372 CONTINUE                                                          S1P10430
      ISW2=1                                                            S1P10440
      CX=2.*CFZ(J, C10)                                                 S1P10450
      CALL CF(I+2, J, 0, 2, CX, X)                                      S1P10460
  373 CONTINUE                                                          S1P10470
      ISW2=1                                                            S1P10480
```

```
      CX=CFZ(J, C10)                                                    S1P10490
      CALL CF (I, J,0, 2, 6.*CX, X)                                     S1P10500
      GO TO 395                                                         S1P10510
  375 CONTINUE                                                          S1P10520
      ISW2=0                                                            S1P10530
      CALL CF (I+2, J, 0, 2, C10, X)                                    S1P10540
  376 CONTINUE                                                          S1P10550
      ISW2=-1                                                           S1P10560
      CALL CF (I-2, J, 0, 2, C10, X)                                    S1P10570
      GO TO 395                                                         S1P10580
  380 CONTINUE                                                          S1P10590
      ISW2=1                                                            S1P10600
      CX=-2.*CFZ(J, C10)                                                S1P10610
      CALL CF (I-2, J, 0, 2, CX, X)                                     S1P10620
  382 CONTINUE                                                          S1P10630
  390 ISW2=1                                                            S1P10640
      CX=CFZ(J, C10)                                                    S1P10650
      CALL CF (I, J, 0, 2,-6.*CX, X)                                    S1P10660
  395 CONTINUE                                                          S1P10670
      IF (MFLAG) 50, 50, 40                                             S1P10680
   40 CONTINUE                                                          S1P10690
      MF=0                                                              S1P10700
      ISW2=0                                                            S1P10710
      CALL CF(I+1,J  ,MF,3,C16,X)                                       S1P10720
      CALL CF(I+1,J  -,MF,2,C7 ,X)                                      S1P10730
      CALL CF(I+1,J  ,MF,1,C4 ,X)                                       S1P10740
      MF=KM1                                                            S1P10750
      CALL CF(I+1,J-1,MF,2,C8 ,X)                                       S1P10760
      CALL CF(I+1,J-1,MF,1,C5 ,X)                                       S1P10770
      CALL CF(I+1,J-1,MF,3,C17,X)                                       S1P10780
      MF=KP1                                                            S1P10790
      ISW2 = -1                                                         S1P10800
      CALL CF(I+1,J+1,MF,1,C5 ,X)                                       S1P10810
      ISW2 = 0                                                          S1P10820
      CALL CF(I+1,J+1,MF,2,C9 ,X)                                       S1P10830
      CALL CF(I+1,J+1,MF,3,C18,X)                                       S1P10840
      IF (I-NCOL) 42, 41, 41                                            S1P10850
   41 ISW2=1                                                            S1P10860
      CX=-4.*CFZ(J, C10)                                                S1P10870
```

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      GO TO 44                                                          S1P10880
   42 IF(I-1) 43,43, 45                                                 S1P10890
   43 ISW2=1                                                            S1P10900
      CX=4.*CFZ( J, C10)                                                S1P10910
   44 CALL CF (I+1,J, 0, 2, CX, X)                                      S1P10920
   45 IF (I-1) 20, 20, 46                                               S1P10930
   46 IF (MFLAG) 50, 50, 20                                             S1P10940
   50 RETURN                                                            S1P10950
      END                                                               S1P10960
*     FORTRAN                                                           S1P10970
      SUBROUTINE EXTRA (X, X1, X2, X3, X4)                              S1P10980
      X=4.*X1-6.*X2+4.*X3-X4                                            S1P10990
      RETURN                                                            S1P11000
      END                                                               S1P11010
*     FORTRAN                                                           S1P11020
      SUBROUTINE GRADE (J)                                              S1P11030
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P11040
      COMMON NCF                                                        S1P11050
      COMMON NDIM, NROW,NCOL,MM,K0,KM1,KM2,KP1,KP2,MFLAG,XM,XLD         S1P11060
      DIMENSION MM(35)                                                  S1P11070
      DO 2 I=37, 40                                                     S1P11080
    2 MM(I)=0                                                           S1P11090
      IF (J) 99, 99, 1                                                  S1P11100
    1 JM=MM(J)                                                          S1P11110
      JM1=MM(J-1)                                                       S1P11120
      JM2= MM(J-2)                                                      S1P11130
      JP1= MM(J+1)                                                      S1P11140
      JP2= MM(J+2)                                                      S1P11150
      IF (J-2) 10, 10, 4                                                S1P11160
    4 IF (J-NROW+1) 5, 30, 30                                           S1P11170
    5 IF (JP2-JM2) 10, 20, 30                                           S1P11180
C     MESH SPACING INCREASING                                           S1P11190
   10 IF (JP1-JM) 11, 12, 12                                            S1P11200
C     DUBLE  MESH SPACING AFTER THIS ROW                                S1P11210
   11 KP1=-1                                                            S1P11220
      KP2=-2                                                            S1P11230
      IF (J-1) 40, 40, 99                                               S1P11240
   12 IF (JP2-JP1)  14, 18, 18                                          S1P11250
   14 KP2=-1                                                            S1P11260
```

```
      IF (J-2) 40, 15, 15                                               S1P11270
   15 IF (JM-JM1) 16, 99, 99                                            S1P11280
C     MESH SPACING CHANGES IN BOTH DIRECTIONS                           S1P11290
   16 KM2=-2                                                            S1P11300
      GO TO 40                                                          S1P11310
   18 IF (J-2) 40, 20, 13                                               S1P11320
   13 IF (JM-JM1) 19, 20, 20                                            S1P11330
C     DOUBLE THE MESH SPACING                                           S1P11340
   19 KM2=-2                                                            S1P11350
      GO TO 40                                                          S1P11360
   20 GO TO 99                                                          S1P11370
C     MESH SPACING IS DECREASING                                        S1P11380
   30 IF (JM-JM1) 32, 32, 31                                            S1P11390
C     CUT MESH SPACING IN HALF                                          S1P11400
   31 KM1=1                                                             S1P11410
      KM2=2                                                             S1P11420
      GO TO 40                                                          S1P11430
   32 IF (JM1-JM2) 37, 37, 33                                           S1P11440
   33 IF (J-NROW+1) 35, 34, 34                                          S1P11450
C     MESH SPACING AT LAST ROW WAS CUT IN HALF                          S1P11460
   34 KM2=1                                                             S1P11470
      GO TO 99                                                          S1P11480
   35 IF (JP1-JM) 34, 34, 36                                            S1P11490
C     SPACING CHANGES IN BOTH DIRECTIONS                                S1P11500
   36 KM2=1                                                             S1P11510
      KP2=2                                                             S1P11520
      GO TO 99                                                          S1P11530
   37 IF (J-NROW+1) 38, 20, 20                                          S1P11540
   38 IF (JP1-JM) 20, 20, 39                                            S1P11550
C     MESH CUT IN HALF AFTER NEXT ROW                                   S1P11560
   39 KP2=2                                                             S1P11570
      GO TO 99                                                          S1P11580
   40 CONTINUE                                                          S1P11590
   99 RETURN                                                            S1P11600
      END                                                               S1P11610
*     FORTRAN                                                           S1P11620
      FUNCTION INDX(II, JJ, KK)                                         S1P11630
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P11640
      COMMON NCF                                                        S1P11650
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      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                        S1P11660
      DIMENSION MM(40)                                                  S1P11670
      I=II                                                              S1P11680
      J=JJ                                                              S1P11690
      K=KK                                                              S1P11700
       IF (MFLAG) 100, 100, 200                                         S1P11710
  100 CONTINUE                                                          S1P11720
      IF (IOPT2) 10, 10, 20                                             S1P11730
   10 IF (I-1) 1, 1, 5                                                  S1P11740
    1 IF (K-1) 2, 2, 3                                                  S1P11750
    2 INDX= (J-1)*2                                                     S1P11760
      GO TO 50                                                          S1P11770
    3 INDX= J*2-1                                                       S1P11780
      GO TO 50                                                          S1P11790
    5 INDX= 3*J+K-4                                                     S1P11800
      GO TO 50                                                          S1P11810
   20 IF (I-1) 21, 21, 29                                               S1P11820
   21 IF (K-1) 22, 22, 24                                               S1P11830
   22 INDX=J*2-1                                                        S1P11840
      GO TO 50                                                          S1P11850
   24 INDX=J*2                                                          S1P11860
      GO TO 50                                                          S1P11870
   29 INDX=3*J+K-3                                                      S1P11880
      GO TO 50                                                          S1P11890
  200 IF (I-NCOL) 201, 201, 220                                         S1P11900
  201 IF (J-NROW) 202, 202, 210                                         S1P11910
  202 IF (J) 230, 230, 205                                              S1P11920
  205 INDX= (I-1)*(NROW+6)*3+3*J+K+6                                    S1P11930
      GO TO 50                                                          S1P11940
  210 IF (IOPT2) 211,211,216                                            S1P11950
  211 INDX=3*(NROW+NCOL-I) +2+K                                         S1P11960
  212 IF (I-1) 214, 214, 50                                             S1P11970
  214 IF (K-3) 50, 215, 215                                             S1P11980
  215 INDX=INDX-1                                                       S1P11990
      GO TO 50                                                          S1P12000
  216 INDX=3*(NROW+NCOL+NCOL-I)+K+5                                     S1P12010
      GO TO 212                                                         S1P12020
  220 INDX=3*J+K-4                                                      S1P12030
      IF (IOPT2) 50, 50, 221                                            S1P12040
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  221 INDX=INDX+3*NCOL+3                                                        S1P12050
      GO TO 50                                                                  S1P12060
  230 INDX=3*I+K-4                                                              S1P12070
      IF (I-1) 231, 231, 50                                                     S1P12080
  231 IF (K-1) 232, 232, 50                                                     S1P12090
  232 INDX=INDX+1                                                               S1P12100
   50 RETURN                                                                    S1P12110
      END                                                                       S1P12120
*     FORTRAN                                                                   S1P12130
      SUBROUTINE MTX (X, I, M)                                                  S1P12140
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8             S1P12150
      COMMON NCF                                                                S1P12160
      COMMON NDIM, NROW,NCOL,MM,I1,KM1,KM2,KP1,KP2,MFLAG,XM,XLD                 S1P12170
      COMMON ISW1, ISW2, ISW3                                                   S1P12180
      DIMENSION MM(35)                                                          S1P12190
      DIMENSION X(72, 72)                                                       S1P12200
       I1=0                                                                     S1P12210
      DO 1 II=1, NDIM                                                           S1P12220
      DO 1 JJ=1, NDIM                                                           S1P12230
    1 X(II, JJ)=0.                                                              S1P12240
      DO 100 J=1, NROW                                                          S1P12250
      ISW1=J                                                                    S1P12260
      IF (XM) 50, 50, 7                                                         S1P12270
    7 CALL GRADE (J)                                                            S1P12280
   50 IF (J-1) 57, 57, 58                                                       S1P12290
   57 IF (IOPT2) 59, 59, 58                                                     S1P12300
   58 I1=I1+1                                                                   S1P12310
      CALL EQ1 (X, I1, I, J, M)                                                 S1P12320
   59 IF (I-1) 61, 61, 60                                                       S1P12330
   60 I1=I1+1                                                                   S1P12340
      CALL EQ2 (X, I1, I, J, M)                                                 S1P12350
   61 I1=I1+1                                                                   S1P12360
      CALL EQ3 ( X, I1, I, J, M)                                                S1P12370
  100 CONTINUE                                                                  S1P12380
      RETURN                                                                    S1P12390
      END                                                                       S1P12400
*     FORTRAN                                                                   S1P12410
*     LIST                                                                      S1P12420
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      SUBROUTINE MTXS (X, Y, II, M)                                     S1P12430
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P12440
      COMMON NCF                                                        S1P12450
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                        S1P12460
      COMMON ISW1, ISW2, ISW3                                           S1P12470
      COMMON A, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12       S1P12480
      COMMON B, B1, B2, B3, B4, B5, B6, B7, B8, B9, B10                 S1P12490
      COMMON C, C1, C2, C3, C4, C5, C6, C7, C8,C9, C10,C11,C12,C13,C14, S1P12500
     1   C15, C16, C17, C18, C19                                        S1P12510
      COMMON FILL                                                       S1P12520
      DIMENSION FILL(1188)                                              S1P12530
      DIMENSION MM(40)                                                  S1P12540
C     MULTIPLICATION BY A SINGLE DIAGONAL                               S1P12550
      DIMENSION X(72, 72), Y(72, 72)                                    S1P12560
      I=II                                                              S1P12570
    3 IF (M-1) 20, 100, 100                                             S1P12580
C     CLEAR OUT Y                                                       S1P12590
   20 DO 23 J=1, NDIM                                                   S1P12600
   23 Y(J,1)=0.                                                         S1P12610
      L1=1                                                              S1P12620
      GO TO 2                                                           S1P12630
  100 L1=NDIM                                                           S1P12640
      IF (M-1) 2,2,50                                                   S1P12650
C     FORM A*X AND STORE IN Y                                           S1P12660
    2 DO 5 J=1,NROW                                                     S1P12670
    6 CONTINUE                                                          S1P12680
    7 I1=INDX (I, J, 2)                                                 S1P12690
      I2=I1+1                                                           S1P12700
       J1=INDX (I-2, J, 3)                                              S1P12710
      J2=J1-1                                                           S1P12720
      IF (I-3) 31, 31, 32                                               S1P12730
   31 CC=0.                                                             S1P12740
      GO TO  33                                                         S1P12750
   32 IF(I-NCOL) 322,321, 321                                           S1P12760
  321 CC= -2.*CFZ(J, C10)                                               S1P12770
      GO TO 33                                                          S1P12780
  322 CC=-CFZ(J, C10)                                                   S1P12790
   33 BB=CFZ(J, B10)                                                    S1P12800
      CC2= CFZ (J, C13)                                                 S1P12810
      DO 4 K=1, L1                                                      S1P12820
```

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      Y(I1, K)=Y(I1, K)-X( J1, K)*BB                                    S1P12830
    4 Y(I2, K)=Y(I2, K)+X (J2, K)*CC+X (J1, K)*CC2                      S1P12840
    5 CONTINUE                                                          S1P12850
      GO TO 99                                                          S1P12860
C     FORM  X*E AND STORE IN Y                                          S1P12870
   50 CONTINUE                                                          S1P12880
      DO 60 J=1, NROW                                                   S1P12890
   51 CONTINUE                                                          S1P12900
   52 IF (I-1) 49, 49, 48                                               S1P12910
   49 CC=2.*CFZ(J, C13)                                                 S1P12920
      CC2=-2.*CFZ(J, C10)                                               S1P12930
      BB=0.                                                             S1P12940
      GO TO 57                                                          S1P12950
   48 CC= CFZ (J, C13)                                                  S1P12960
      CC2=-CFZ(J, C10)                                                  S1P12970
      BB= CFZ (J, B10)                                                  S1P12980
   57 I2= INDX (I, J, 3)                                                S1P12990
      I1=I2-1                                                           S1P13000
      J1= INDX(I+2, J, 2)                                               S1P13010
      J2=J1+1                                                           S1P13020
   53 DO 54 K=1, L1                                                     S1P13030
   54 Y(K, J1)=Y(K, J1)-X(K, I2)*CC2                                    S1P13040
   55 DO 58 K=1, L1                                                     S1P13050
   58 Y(K, J2)= Y(K, J2)+X(K, I1)*BB+X(K, I2)*CC                        S1P13060
   60 CONTINUE                                                          S1P13070
   99 RETURN                                                            S1P13080
      END                                                               S1P13090
*     FORTRAN                                                           S1P13100
      SUBROUTINE NORM (X, CONS, K)                                      S1P13110
      DIMENSION X(19), Y(19)                                            S1P13120
      DO 1 I=1,K                                                        S1P13130
    1 Y(I)=ABSF(X(I))                                                   S1P13140
      DO 10 I=2,K                                                       S1P13150
      IF (Y(1)-Y(I)) 2,10,10                                            S1P13160
    2 TEMP=Y(1)                                                         S1P13170
      Y(1)=Y(I)                                                         S1P13180
      Y(I)=TEMP                                                         S1P13190
   10 CONTINUE                                                          S1P13200
      DO 20 I=1,K                                                       S1P13210
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   20 X(I)=X(I)/Y                                                        S1P13220
      CONS=CONS/Y                                                        S1P13230
      RETURN                                                             S1P13240
      END                                                                S1P13250
*     FORTRAN                                                            S1P13260
      SUBROUTINE INVERT(A,IMAX,ISING)                                    S1P13270
C     SUBROUTINE TO INVERT A MATRIX                                      S1P13280
      DIMENSION A(72, 72), IN(72), TEMP(72)                              S1P13290
      ISING=0                                                            S1P13300
      N=IMAX                                                             S1P13310
      IMAXO=N-1                                                          S1P13320
      I1=1                                                               S1P13330
    1 I3=I1                                                              S1P13340
      IN(I1)=0                                                           S1P13350
      SUM=ABSF(A(I1,I1))                                                 S1P13360
      DO3I=I1,N                                                          S1P13370
      IF(SUM-ABSF(A(I,I1)))2,3,3                                         S1P13380
    2 I3=I                                                               S1P13390
      IN(I1)=I                                                           S1P13400
      SUM=ABSF(A(I,I1))                                                  S1P13410
    3 CONTINUE                                                           S1P13420
      IF(I3-I1)4,6,4                                                     S1P13430
    4 DO5J=1,N                                                           S1P13440
      SUM=A(I1,J)                                                        S1P13450
      A(I1,J)=A(I3,J)                                                    S1P13460
    5 A(I3,J)=SUM                                                        S1P13470
    6 I3=I1+1                                                            S1P13480
      IF(A(I1,I1))97,99,97                                               S1P13490
   97 DO7I=I3,N                                                          S1P13500
    7 A(I,I1)=A(I,I1)/A(I1,I1)                                           S1P13510
      J2=I1-1                                                            S1P13520
      IF(J2)8,11,8                                                       S1P13530
    8 DO9J=I3,N                                                          S1P13540
    9 A(I1,J)=A(I1,J)-DPSUM (A,I1,J,1,J2)                                S1P13550
   11 J2=I1                                                              S1P13560
      I1=I1+1                                                            S1P13570
      DO12I=I1,N                                                         S1P13580
   12 A(I,I1)=A(I,I1)-DPSUM(A, I, I1, 1, J2)                             S1P13590
      IF(I1-N)1,14,1                                                     S1P13600
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   14 DO600JP=1,N                                                S1P13610
      J=N+1-JP                                                   S1P13620
      A(J,J)=1.0/A(J,J)                                          S1P13630
      IF(J-1)603,700,603                                         S1P13640
  603 DO600IP=2,J                                                S1P13650
      I=J+1-IP                                                   S1P13660
      IPO=I+1                                                    S1P13670
      SUM=-DPSUM (A,I,J,IPO,J)                                   S1P13680
  600 A(I,J)=SUM/A(I,I)                                          S1P13690
  700 DO151J=1,IMAXO                                             S1P13700
      JPO=J+1                                                    S1P13710
      DO151I=JPO,N                                               S1P13720
      IMO=I-1                                                    S1P13730
      SUM=-DPSUM (A,I,J,J+1,IMO)                                 S1P13740
      SUM=SUM-A(I,J)                                             S1P13750
  151 A(I,J)=SUM                                                 S1P13760
      DO901I=1,N                                                 S1P13770
      DO900J=1,N                                                 S1P13780
      IF (I-J) 897,897,898                                       S1P13790
  897 TEMP(J)=DPSUM(A,I,J,J+1,N)                                 S1P13800
      TEMP(J)=TEMP(J)+A(I,J)                                     S1P13810
      GO TO 900                                                  S1P13820
  898 TEMP(J)=DPSUM(A,I,J,I,N)                                   S1P13830
  900 CONTINUE                                                   S1P13840
      DO901J=1,N                                                 S1P13850
  901 A(I,J)=TEMP(J)                                             S1P13860
      DO500I=2,N                                                 S1P13870
      M=N+1-I                                                    S1P13880
      IF(IN(M))502,500,502                                       S1P13890
  502 ISS=IN(M)                                                  S1P13900
      DO503L=1,N                                                 S1P13910
      SUM=A(L,ISS)                                               S1P13920
      A(L,ISS)=A(L,M)                                            S1P13930
  503 A(L,M)=SUM                                                 S1P13940
  500 CONTINUE                                                   S1P13950
      GO TO 805                                                  S1P13960
   99 ISING=1                                                    S1P13970
  805 RETURN                                                     S1P13980
      END                                                        S1P13990
```

```
*       FORTRAN                                                          S1P14000
        SUBROUTINE STORE (X, II)                                         S1P14010
        COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8    S1P14020
        COMMON NCF                                                       S1P14030
        COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                       S1P14040
        COMMON ISW1, ISW2, ISW3                                          S1P14050
        COMMON A                                                         S1P14060
        COMMON TMP, YK, YL                                               S1P14070
        DIMENSION TMP (5184), YK(5184), YL(5184)                         S1P14080
        DIMENSION A(1232)                                                S1P14090
        DIMENSION X(59)                                                  S1P14100
        DIMENSION MM(40)                                                 S1P14110
        N2= (NROW+6)*3                                                   S1P14120
        NC1=NCOL+1                                                       S1P14130
        IF (MFLAG) 100, 100, 200                                         S1P14140
    100 N1=(II-1)*N2+10                                                  S1P14150
        I2=0                                                             S1P14160
        DO 110 J=1, NROW                                                 S1P14170
        IF (J-1) 101, 101, 103                                           S1P14180
    101 IF (IOPT2) 104, 104, 103                                         S1P14190
    103 I2=I2+1                                                          S1P14200
        TMP(N1)=X(I2)                                                    S1P14210
    104 IF (II-1) 107, 107, 106                                          S1P14220
    106 I2=I2+1                                                          S1P14230
        TMP (N1+1)=X(I2)                                                 S1P14240
    107 I2=I2+1                                                          S1P14250
        TMP (N1+2)=X(I2)                                                 S1P14260
    110 N1=N1+3                                                          S1P14270
        GO TO 999                                                        S1P14280
    200 IF (IOPT2) 220, 220, 201                                         S1P14290
    201 I2=II*270                                                        S1P14300
        DO 210 I=1, NCOL                                                 S1P14310
        N1= (I-1)*N2+1                                                   S1P14320
        I2=I2+1                                                          S1P14330
        TMP(N1+3)=YK(I2)                                                 S1P14340
        IF (I-1) 208, 208, 204                                           S1P14350
    204 I2=I2+1                                                          S1P14360
        TMP(N1+4)=YK(I2)                                                 S1P14370
    208 I2=I2+1                                                          S1P14380
```

```
      TMP(N1+2)=YK(I2)                                                   S1P14390
      TMP(N1+5)=TMP(N1+11)                                               S1P14400
  210 CONTINUE                                                           S1P14410
      N1=NC1*N2+4                                                        S1P14420
      TMP(N1)=YK(I2+1)                                                   S1P14430
      TMP(N1+1)=YK(I2+2)                                                 S1P14440
      TMP(N1+2)=YK(I2+3)                                                 S1P14450
      TMP(N1+6)=YK(I2+4)                                                 S1P14460
      I2=I2+4                                                            S1P14470
      GO TO 222                                                          S1P14480
  220 I2=I1*270                                                          S1P14490
  222 NO=NC1*N2+10                                                       S1P14500
      N1=NO+N2                                                           S1P14510
      NN=NO-N2-N2                                                        S1P14520
      TMP(NO+1)=YK(I2+1)                                                 S1P14530
      TMP(N1+2)=YK(I2+2)                                                 S1P14540
      I2=I2+2                                                            S1P14550
      TMP  (NO+2)=TMP(NN+2)                                              S1P14560
  230 DO 240 J=2, NROW                                                   S1P14570
      NO=NO+3                                                            S1P14580
      N1=N1+3                                                            S1P14590
      NN=NN+3                                                            S1P14600
      TMP(NO)=YK(I2+1)                                                   S1P14610
      TMP(NO+1)=  YK(I2+2)                                               S1P14620
      TMP(NO+2)=  TMP(NN+2)                                              S1P14630
      TMP(N1+2)=YK(I2+3)                                                 S1P14640
  240 I2=I2+3                                                            S1P14650
      NO=NO+6                                                            S1P14660
      TMP(NO)=YK(I2+1)                                                   S1P14670
      TMP(NO+1)=YK(I2+2)                                                 S1P14680
      TMP(NO+2)=YK(I2+3)                                                 S1P14690
      I2=I2+3                                                            S1P14700
      DO 250 I=1, NCOL                                                   S1P14710
      I1=NCOL+1-I                                                        S1P14720
      N1=I1*N2-5                                                         S1P14730
      I2=I2+1                                                            S1P14740
      TMP(N1)=YK(I2)                                                     S1P14750
      TMP(N1+2)=TMP(N1-4)                                                S1P14760
      IF (I1-1) 252, 252, 251                                            S1P14770
```

```
  251 I2=I2+1                                                                S1P14780
      TMP(N1+1)=YK(I2)                                                       S1P14790
  252 I2=I2+1                                                                S1P14800
      TMP(N1+5)=YK(I2)                                                       S1P14810
  250 CONTINUE                                                               S1P14820
  999 RETURN                                                                 S1P14830
      END                                                                    S1P14840
*     FORTRAN                                                                S1P14850
      SUBROUTINE STRESS (II,JJ,KK)                                           S1P14860
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8          S1P14870
      COMMON NCF                                                             S1P14880
      COMMON NDIM, NROW,NCOL,MM,I1,KM1,KM2,KP1,KP2,MFLAG,XM,XLD              S1P14890
      COMMON ISW1, ISW2, ISW3                                                S1P14900
      COMMON A                                                               S1P14910
      COMMON   TMP, YK, YL                                                   S1P14920
      COMMON T1, T2, XX, XX1, Z, Z1, Z2                                      S1P14930
      COMMON ZNU, THC, PH1, FF, RH, DD,XXH, XK                               S1P14940
      COMMON ZETA                                                            S1P14950
      COMMON TE, TI, TO, OC, TC, TD, DDLD                                    S1P14960
      DIMENSION A(1232)                                                      S1P14970
      DIMENSION MM(35)                                                       S1P14980
      DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89)     S1P14990
      DIMENSION TMP(5184), YK(4, 1296), YL(4,4,324)                          S1P15000
      DIMENSION ZETA (30)                                                    S1P15010
  101 FORMAT (I3, 1H, I3, 1P9E12.4)                                          S1P15020
      K = KK                                                                 S1P15030
      J=JJ                                                                   S1P15040
      NC1=NCOL+1                                                             S1P15050
      NR1=NROW+1                                                             S1P15060
      IF (XM) 1, 1,  5                                                       S1P15070
    1 XH=XXH                                                                 S1P15080
      GO TO 10                                                               S1P15090
    5 J1=XMAXOF (J, 1)                                                       S1P15100
      J1=MM(J1)                                                              S1P15110
      XH= XXH/2.**J1                                                         S1P15120
   10 I=II                                                                   S1P15130
      U = DEF (I, J, 1, 0)                                                   S1P15140
      V = DEF (I, J, 2, 0)                                                   S1P15150
      W = DEF (I, J, 3, 0)                                                   S1P15160
```

```
      UX=(DEF(I,J-1,1, KM1)-DEF(I,J+1,1,KP1))/(2.*XH)
      UT=(DEF(I+1,J,1, 0)-DEF(I-1, J, 1, 0))/ (2.*XK)
      VX= (DEF(I , J-1, 2, KM1)- DEF (I, J+1, 2, KP1))/(2.*XH)
      VT= (DEF( I+1, J, 2, 0) -DEF (I-1, J, 2, 0))/(2.*XK)
      WX= (DEF(I, J-1, 3, KM1)-DEF(I, J+1, 3, KP1))/(2.*XH)
      WT= (DEF(I+1, J, 3, 0)-DEF(I-1, J, 3, 0))/(2.*XK)
      VXX= (DEF (I, J-1, 2, KM1)-2.*DEF (I, J,2, 0)+DEF(I,J+1,2,KP1))/(
     1 XH*XH)
      VXT= (DEF(I+1, J-1, 2,KM1)-DEF(I+1,J+1, 2,KP1)- DEF (I-1,J-1,2,KM1
     1 ) + DEF (I-1, J+1, 2, KP1))/(4.*XH*XK)
      VTX=VXT
      VTT=(DEF(I+1,J,2,0)-2.*DEF(I,J,2,0)+DEF(I-1,J,2,0))/XK**2
      WXX= (DEF(I,J-1,3,KM1)-2.*DEF(I,J,3,0)+DEF(I,J+1,3,KP1))/XH**2
      WXT= (DEF(I+1, J-1,3,KM1)-DEF(I+1,J+1,3,KP1)-DEF(I-1,J-1, 3,KM1)+
     1 DEF (I-1, J+1,3,KP1))/(4.*XH*XK)
      WTX=WXT
      WTT= (DEF (I+1,J,3,0)-2.*DEF(I,J,3,0)+DEF(I-1,J,3,0))/XK**2
      WXXX= (DEF(I,J-2,3,KM2)-2.*DEF(I, J-1,3,KM1)+2.*DEF(I,J+1,3,KP1)
     1 -DEF(I,J+2,3,KP2))/(2.*XH**3)
      WXTT= (DEF (I+1, J-1,3,KM1)-2.*DEF(I,J-1,3,KM1)+2.*DEF(I,J+1,3,KP1
     1 )-DEF(I+1,J+1,3,KP1)+DEF(I-1,J-1,3,KM1)-DEF(I-1,J+1,3,KP1))/(2.*
     2 XH*XK*XK)
      WTTX=WXTT
      WTTT= (DEF(I+2,J,3,0)-2.*DEF(I+1,J,3,0)+2.*DEF(I-1,J,3,0)-DEF(I-2,
     1 J,3,0))/(2.*XK**3)
      WXXT= (DEF(I+1,J-1,3,KM1)-2.*DEF(I+1,J,3,0)+2.*DEF (I-1,J,3,0)+
     1 DEF(I+1, J+1,3,KP1)-DEF(I-1,J-1,3,KM1)-DEF(I-1,J+1,3,KP1))/(2.*
     2 XH*XH*XK)
      X=ZETA(J+1)
      SI  = SINF(X)
      CO  = COSF(X)
      CSC = 1./SI
      COT = CO *CSC
      EPSX = UX+W
      EPST = COT*U + CSC*VT + W
      GAM = CSC*UT + VX - COT*V
      XLX1 = UX - WXX
      XLX2 = CSC*(VT - CSC*WTT + CO *(U-WX))
      XLX12 = CSC*(CO *V + COT*WT - WXT - UT) + VX
```

```
      XXX = UXX - WXXX                                                  S1P15560
      XXT = UXT - WXXT                                                  S1P15570
      XTX = CSC*(CO *(UX-WXX) + SI *(WX-U) - CSC*WTTX + VTX             S1P15580
     1    - COT*(CO *(U-WX)- 2.*CSC*WTT + VT))                          S1P15590
      XTT = CSC*(CO *(UT-WXT) - CSC*WTTT + VTT)                         S1P15600
      XXTX = CSC*(COT*WXT + CO *VX - SI *V - WXXT - UXT - CSC*CSC*(WT   S1P15610
     1    - CO *(WXT + UT - COT*WT - CO *V))) + VXX                     S1P15620
      XXTT = VXT + CSC*(UTT - WXTT - CO *(VT - CSC*WTT))                S1P15630
      IF (MFLAG) 20, 40, 40                                             S1P15640
   20 CONTINUE                                                          S1P15650
      OMEGAX = U - WX                                                   S1P15660
      OMEGAT = V - CSC*WT                                               S1P15670
      PHI = .5*(VX + CSC*(CO *V - UT))                                  S1P15680
      WRITE OUTPUT TAPE 6, 101, J, I, EPSX, EPST, GAM,XLX1,XLX2,XLX12,  S1P15690
     1 OMEGAX, OMEGAT, PHI                                              S1P15700
      GO TO 99                                                          S1P15710
   40 CONTINUE                                                          S1P15720
      ANX = EPSX + ZNU*EPST - TC                                        S1P15730
      ANT = EPST + ZNU*EPSX - TC                                        S1P15740
      ANXT = GAM + 2.*DD*XLX12                                          S1P15750
      ANTX = ANXT                                                       S1P15760
      AMX = XLX1 + ZNU*XLX2 - TD*RH                                     S1P15770
      AMT = XLX2 + ZNU*XLX1 - TD*RH                                     S1P15780
      AMXT = XLX12                                                      S1P15790
      AMTX = AMXT                                                       S1P15800
      AMXTT = XXTT                                                      S1P15810
      AMXTX =  XXTX                                                     S1P15820
      AQX = XXX + ZNU*XTX + (1.-ZNU)*CSC*(XXTX + CO *(XLX1-XLX2))       S1P15830
      AQT = XTT + ZNU*XXT + (1.-ZNU)*(2.*XLX12*COT + XXTX)              S1P15840
      IF (K) 49, 49, 47                                                 S1P15850
   47 YL(1, K, I)=ANX                                                   S1P15860
      YL(2, K, I)=ANT                                                   S1P15870
      YL(3, K, I)=AMX                                                   S1P15880
      YL(4, K, I)=AMT                                                   S1P15890
   49 CONTINUE                                                          S1P15900
      IF (MFLAG) 45, 45, 46                                             S1P15910
   45  WRITE OUTPUT TAPE 6,101,J,I, AMX , AMT, AMXT, AQX , AQT          S1P15920
      GO TO 48                                                          S1P15930
   46  WRITE OUTPUT TAPE 6,101,J,I, ANX,ANT,ANXT, ANTX                  S1P15940
```

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   48 CONTINUE                                     S1P15950
      IF (J) 60, 60, 51                            S1P15960
   51 IF (NR1-J) 70, 70, 52                        S1P15970
   52 IF (NC1-I) 80, 80, 99                        S1P15980
C     LOWER BOUNDARY                               S1P15990
   60 J3=NC1+NR1+2+NC1-I                           S1P16000
      YK(1,J3) = ANXT + 2.*DD*AMXT                 S1P16010
      YK(2,J3) = ANX                               S1P16020
      YK(3,J3) = AQX + CSC*(1.-ZNU)*AMXTT          S1P16030
      YK(4,J3) = AMX                               S1P16040
      IF (I-NC1) 99, 69, 69                        S1P16050
C     SPECIAL POINT                                S1P16060
   69 K1=2*(NC1+NR1)+1                             S1P16070
      YK(1, K1)=-2.*AMXT                           S1P16080
      GO TO 80                                     S1P16090
C     UPPER BOUNDARY                               S1P16100
   70 YK(1,I) = ANXT + 2.*DD*AMXT                  S1P16110
      YK(2,I) = ANX                                S1P16120
      YK(3,I) = -AQX - CSC*(1.-ZNU)*AMXTT          S1P16130
      YK(4,I) = AMX                                S1P16140
      IF (I-NC1) 99, 79, 79                        S1P16150
C     SPECIAL CORNER POINT                         S1P16160
   79 K1=2*(NC1+NR1)                               S1P16170
      YK(1, K1)=+2.*AMXT                           S1P16180
C     RIGHT BOUNDARY                               S1P16190
   80 J3=NC1+NR1+1-J                               S1P16200
      YK(1,J3) = -ANTX - 2.*DD*AMXT                S1P16210
      YK(2,J3) = ANT                               S1P16220
      YK(3,J3) = AQT + (1.-ZNU)*AMXTX              S1P16230
      YK(4,J3) = AMT                               S1P16240
   99 RETURN                                       S1P16250
      END                                          S1P16260
*     FORTRAN                                      S1P16270
      SUBROUTINE ZERO (X,N)                        S1P16280
      DIMENSION X(8500)                            S1P16290
      DO 1 I=1,N                                   S1P16300
    1 X(I)=0.                                      S1P16310
      RETURN                                       S1P16320
      END                                          S1P16330
```

```
*      FORTRAN                                                          S1P16340
*      FAP                                                              S1P16350
        COUNT   90                                                      S1P16360
*       MATRIX MULTIPLICATION IN DOUBLE PRECISION                       S1P16370
*       MATM (X, Y, Z, NR, NC, NCY)                                     S1P16380
*       COMPUTE Z=X*Y.  NR AND NC ARE NUMBER OF ROWS AND COLS IN X.  NCYS1P16390
*           IS NUMBER OF COLS IN Y.  Z=Y O.K. BUT NOT Z=X.              S1P16400
        ENTRY   MATM                                                    S1P16410
MATM    SXA     AXT,1                                                   S1P16420
        SXA     AXT+1,2                                                 S1P16430
        SXA     AXT+2,4                                                 S1P16440
        CLA     1,4         X-MATRIX                                    S1P16450
        STA     AX                                                      S1P16460
        CLA     2,4                                                     S1P16470
        STA     AY                                                      S1P16480
        CLA     3,4                                                     S1P16490
        STA     AZ                                                      S1P16500
        CLA*    4,4        NR OF ROWS IN X                              S1P16510
        ARS     18                                                      S1P16520
        STA     NR                                                      S1P16530
        CLA*    5,4         NR OF COLS IN X                             S1P16540
        ARS     18                                                      S1P16550
        STA     NC                                                      S1P16560
        CLA*    6,4                                                     S1P16570
        ARS     18                                                      S1P16580
        STA     NCY                                                     S1P16590
        CLA     =1                                                      S1P16600
        STO     J                                                       S1P16610
MTO     LDQ     RWDIM                                                   S1P16620
        MPY     J                                                       S1P16630
        XCA                                                             S1P16640
        SSM                                                             S1P16650
        ADD     AZ                                                      S1P16660
        ADD     RWDIM                                                   S1P16670
        ADD     =1                                                      S1P16680
        STA     AZIJ                                                    S1P16690
        LDQ     RWDIM                                                   S1P16700
        MPY     J                                                       S1P16710
        XCA                                                             S1P16720
```

```
         SSM                                   S1P16730
         ADD    AY                             S1P16740
         ADD    RWDIM                          S1P16750
         ADD    =1                             S1P16760
         STA    YCOL                           S1P16770
         LXA    NR,1                           S1P16780
         SXD    MT4,1                          S1P16790
         AXT    1,1                            S1P16800
         LXA    NC,2                           S1P16810
YCOL     CLA    **,2                           S1P16820
         STO    TEM,2                          S1P16830
         TIX    YCOL,2,1                       S1P16840
MT1      SXA    I,1                            S1P16850
         LDQ    RWDIM                          S1P16860
         MPY    NC                             S1P16870
         XCA                                   S1P16880
         PAX    ,4                             S1P16890
         CLA    RWDIM                          S1P16900
         ADD    AX                             S1P16910
         ADD    =1                             S1P16920
         SUB    I                              S1P16930
         STA    MT2                            S1P16940
         STA    AXIK                           S1P16950
         LXA    NC,2                           S1P16960
         STZ    TEM                            S1P16970
         STZ    TEM+1                          S1P16980
         PXA    0,0                            S1P16990
MT2      NZT    **,4                           S1P17000
         TXI    MT3+1,2,-1                     S1P17010
AXIK     LDQ    **,4                           S1P17020
AYKJ     FMP    TEM,2                          S1P17030
         DFAD   TEM                            S1P17040
         DST    TEM                            S1P17050
MT3      TNX    *+2,2,1                        S1P17060
         TIX    MT2,4,ROWD                     S1P17070
AZIJ     STO    **,1                           S1P17080
         TXI    *+1,1,1                        S1P17090
MT4      TXL    MT1,1,**       **=NR           S1P17100
         CLA    J                              S1P17110
```

```
         ADD     =1                                                     S1P17120
         CAS     NCY                                                    S1P17130
         TRA     AXT                                                    S1P17140
         TRA     *+1                                                    S1P17150
         STO     J                                                      S1P17160
         TRA     MTO                                                    S1P17170
AXT      AXT     **,1                                                   S1P17180
         AXT     **,2                                                   S1P17190
         AXT     **,4                                                   S1P17200
         TRA     7,4                                                    S1P17210
RWDIM    DEC     72                                                     S1P17220
ROWD     EQU     72                                                     S1P17230
TEM      BOOL    130                                                    S1P17240
AX       PZE     0                                                      S1P17250
AY       PZE     0                                                      S1P17260
AZ       PZE     0                                                      S1P17270
NR       PZE     0                                                      S1P17280
NC       PZE     0                                                      S1P17290
NCY      PZE     0                                                      S1P17300
I        PZE     0                                                      S1P17310
J        PZE     0                                                      S1P17320
         END                                                            S1P17330
*       FAP                                                             S1P17340
         COUNT   50                                                     S1P17350
*DPSUM FUNCTION DPSUM(A,I,J,K,M). COMPUTE SUM OF A(I,L)*A(L,J), L=K,M.  S1P17360
*        SET DPSUM=0 IF K GREATER THAN M                                S1P17370
*        SET THE VFLD OF RDIM AND ROWDIM TO THE ROW DIMENSION OF A      S1P17380
         ENTRY   DPSUM                                                  S1P17390
DPSUM    CLA*    5,4       LOAD M                                       S1P17400
         CAS*    4,4        COMPARE WITH K                              S1P17410
         TRA     *+4     M IS BIGGER                                    S1P17420
         TRA     *+3      M=K                                           S1P17430
         PXA     0,0     M LESS THAN K     SET  DPSUM=0                 S1P17440
         TRA     6,4                                                    S1P17450
         SXA     AXT,1                                                  S1P17460
         SXA     AXT+1,2                                                S1P17470
         STD     TEST                                                   S1P17480
         CLA     1,4                                                    S1P17490
         ADD     =1                                                     S1P17500
```

```
         STA     AIL                                          S1P17510
         CLA*    2,4                                          S1P17520
         ARS     18                                           S1P17530
         STA     I                                            S1P17540
         CLA*    4,4                                          S1P17550
         PDX     ,2                                           S1P17560
         ARS     18                                           S1P17570
         SUB     =1                                           S1P17580
         XCA                                                  S1P17590
         MPY     RDIM                                         S1P17600
         XCA                                                  S1P17610
         ADD     I                                            S1P17620
         PAX     ,1                                           S1P17630
         CLA*    3,4                                          S1P17640
         ARS     18                                           S1P17650
         SUB     =1                                           S1P17660
         XCA                                                  S1P17670
         MPY     RDIM                                         S1P17680
         XCA                                                  S1P17690
         SSM                                                  S1P17700
         ADD     AIL                                          S1P17710
         STA     ALJ                                          S1P17720
         STZ     SUM                                          S1P17730
         STZ     SUM+1                                        S1P17740
AIL      LDQ     **,1                                         S1P17750
ALJ      FMP     **,2                                         S1P17760
         DFAD    SUM                                          S1P17770
         DST     SUM                                          S1P17780
         TXI     *+1,1,ROWDIM                                 S1P17790
         TXI     *+1,2,1                                      S1P17800
TEST     TXL     AIL,2,**                                     S1P17810
AXT      AXT     **,1                                         S1P17820
         AXT     **,2                                         S1P17830
         TRA     6,4                                          S1P17840
R        COMMON  1                                            S1P17850
SUM      EQU     R+203                                        S1P17860
I        PZE                                                  S1P17870
ROWDIM   EQU     72                                           S1P17880
RDIM     DEC     72                                           S1P17890
```

```
        END                                                            S1P17900
*      FAP                                                             S1P17910
        COUNT    70                                                    S1P17920
*       FUNCTION QDPSUM (A, I, J, K2, J2)                              S1P17930
        ENTRY    QDPSUM                                                S1P17940
QDPSUM  SXA      AXT,1                                                 S1P17950
        SXA      AXT+1,2                                               S1P17960
        SXA      AXT+2,4                                               S1P17970
        CLA      1,4                                                   S1P17980
        STA      DP1                                                   S1P17990
        STA      DP1+1                                                 S1P18000
        LXA      ROWD,1                                                S1P18010
        SXD      DP2,1                                                 S1P18020
        CLA*     2,4                                                   S1P18030
        ARS      18                                                    S1P18040
        STA      I                                                     S1P18050
        CLA*     4,4                                                   S1P18060
        ARS      18                                                    S1P18070
        STA      K2                                                    S1P18080
        ADD      K                                                     S1P18090
        SUB      I                                                     S1P18100
        XCA                                                            S1P18110
        MPY      ROWD                                                  S1P18120
        XCA                                                            S1P18130
        ADD      I                                                     S1P18140
        SUB      =1                                                    S1P18150
        PAX      ,1                                                    S1P18160
        CLA*     3,4                                                   S1P18170
        ARS      18                                                    S1P18180
        STA      I                                                     S1P18190
        CLA      ROWD                                                  S1P18200
        ADD      =1                                                    S1P18210
        SUB      I                                                     S1P18220
        TZE      DP                                                    S1P18230
        CLA      ROWD                                                  S1P18240
        SUB      =1                                                    S1P18250
        PAC      ,2                                                    S1P18260
        SXD      DP3,2                                                 S1P18270
        CLA      I                                                     S1P18280
```

```
        ADD     K                                                    S1P18290
        SUB     K2                                                   S1P18300
        XCA                                                          S1P18310
        MPY     ROWD                                                 S1P18320
        XCA                                                          S1P18330
        SUB     =1                                                   S1P18340
        ADD     K2                                                   S1P18350
        PAX     ,2                                                   S1P18360
        TRA     DPO                                                  S1P18370
DP      AXT     1,2                                                  S1P18380
        SXD     DP3,2                                                S1P18390
        CLA     K                                                    S1P18400
        ADD     K                                                    S1P18410
        ADD     =1                                                   S1P18420
        XCA                                                          S1P18430
        MPY     ROWD                                                 S1P18440
        XCA                                                          S1P18450
        ADD     K2                                                   S1P18460
        SUB     =1                                                   S1P18470
        PAX     ,2                                                   S1P18480
DPO     CLA*    5,4                                                  S1P18490
        ARS     18                                                   S1P18500
        SUB     K2                                                   S1P18510
        ADD     =1                                                   S1P18520
        PAX     ,4                                                   S1P18530
        STZ     TEMP                                                 S1P18540
        STZ     TEMP+1                                               S1P18550
DP1     LDQ     **,1                                                 S1P18560
        FMP     **,2                                                 S1P18570
        DFAD    TEMP                                                 S1P18580
        DST     TEMP                                                 S1P18590
DP2     TXI     *+1,1,**                                             S1P18600
DP3     TXI     *+1,2,**                                             S1P18610
        TIX     DP1,4,1                                              S1P18620
AXT     AXT     **,1                                                 S1P18630
        AXT     **,2                                                 S1P18640
        AXT     **,4                                                 S1P18650
        TRA     6,4                                                  S1P18660
ROWD    DEC     270                                                  S1P18670
```

```
K       DEC     5                                                          S1P18680
I       PZE                                                                S1P18690
K2      PZE                                                                S1P18700
TEMP    BOOL    77774                                                      S1P18710
        END                                                                S1P18720
*      FAP                                                                 S1P18730
        COUNT   150                                                        S1P18740
        ENTRY   CLOCK                                                      S1P18750
        ENTRY   WCKA                                                       S1P18760
        ENTRY   WCKP                                                       S1P18770
*       SUBROUTINE    CLOCK                                                S1P18780
*                          ****************                               *S1P18790
*       THIS SUBROUTINE PLACES THE CLOCK IN A GIVEN LOCATION SPECIFIED    *S1P18800
*       BY THE CALL STATEMENT(  THAT IS                                   *S1P18810
*       CALL CLOCK(LOCATION TO  E STOREED     IN FORTRAN  OR              *S1P18820
*       CALL CLOCK      (FOR ABSOLUTE ASSEMBLIES USE  TSX CLOCK           *S1P18830
*       PZE   (LOCATION TO BE STORED)   IN  FAP                           *S1P18840
*               OR                                                        *S1P18850
*       SVN   (LOCATION TO BE STORED)  GIVES THE CLOCK IN FLOATING POINT*S1P18860
*       PZE  (LOCATION TO BE STORED) GIVES THE CLOCK IN BCD               *S1P18870
*       IN FORTRAN THE CLOCK WILL ALWAYS BE GIVEN IN FLOATING POINT       *S1P18880
*       THE CLOCK IS ALSO PRINTED ON-LINE                                 *S1P18890
*                          ****************                               *S1P18900
        SPACE   3                                                          S1P18910
CLOCK   BSS     0                                                          S1P18920
WCKA    BSS     0                                                          S1P18930
WCKP    BSS     0                                                          S1P18940
        SXA     CLOCK+55,1                                                 S1P18950
        SXA     CLOCK+56,2                                                 S1P18960
        SXA     CLOCK+57,4                                                 S1P18970
        RPRA                                                               S1P18980
        SPRA    10                                                         S1P18990
        RCHA    CLOCK+105                                                  S1P19000
        TCOA    *                                                          S1P19010
        STZ     CLOCK+61                                                   S1P19020
        STZ     CLOCK+62                                                   S1P19030
        CLA     CLOCK+227                                                  S1P19040
        STO     CLOCK+218                                                  S1P19050
        AXT     0,3                                                        S1P19060
```

```
       AXT     2,4                                              S1P19070
       LDQ     CLOCK+104,1                                      S1P19080
       PXD     0,0                                              S1P19090
       CAQ     CLOCK+153,,1                                     S1P19100
       CVR     CLOCK+217,,6                                     S1P19110
       ORS     CLOCK+63,4                                       S1P19120
       TIX     *-4,4,1                                          S1P19130
       CLA     CLOCK+226,2                                      S1P19140
       STO     CLOCK+218                                        S1P19150
       TXI     *+1,2,1                                          S1P19160
       TXI     *+1,1,2                                          S1P19170
       TXL     CLOCK+12,1,17                                    S1P19180
       PXD     0,0                                              S1P19190
       LDQ     CLOCK+61                                         S1P19200
       LGL     30                                               S1P19210
       LDQ     CLOCK+62                                         S1P19220
       LGL     18                                               S1P19230
       RQL     6                                                S1P19240
       LGL     12                                               S1P19250
       SLW     CLOCK+61                                         S1P19260
       LXA     CLOCK+57,4                                       S1P19270
       CAL     1,4                                              S1P19280
       ARS     18                                               S1P19290
       TZE     CLOCK+55                                         S1P19300
       PXD     0,0                                              S1P19310
       LDQ     CLOCK+61                                         S1P19320
       CAQ     CLOCK+113,,4                                     S1P19330
       STQ     CLOCK+61                                         S1P19340
       ARS     18                                               S1P19350
       ADD     =0233000000000                                   S1P19360
       FAD     =0233000000000                                   S1P19370
       XCA                                                      S1P19380
       FMP     =1.E2                                            S1P19390
       STO     CLOCK+87                                         S1P19400
       PXD     0,0                                              S1P19410
       LDQ     CLOCK+61                                         S1P19420
       CAQ     CLOCK+133,,2                                     S1P19430
       ARS     18                                               S1P19440
```

```
      ADD      =0233000000000                                       S1P19450
      FAD      =0233000000000                                       S1P19460
      FAD      CLOCK+87                                             S1P19470
      FDP      =1.E2                                                S1P19480
      STQ      CLOCK+61                                             S1P19490
      AXT      **,1                                                 S1P19500
      AXT      **,2                                                 S1P19510
      AXT      **,4                                                 S1P19520
      CLA      CLOCK+61                                             S1P19530
      STO*     1,4                                                  S1P19540
      TRA      2,4                                                  S1P19550
      PZE                                                           S1P19560
      PZE                                                           S1P19570
      OCT      ,,,,,,,,,,,,,,,,,,,,,,,                              S1P19580
      BSS      18                                                   S1P19590
      IOCP     CLOCK+63,,18       WRITE                             S1P19600
      IOCPN    CLOCK+87,,2        READ   (NON-TRANSMITTAL)          S1P19610
      IOCP     CLOCK+81,,2        WRITE                             S1P19620
      IOCPN    CLOCK+87,,2        READ   (NON-TRANSMITTAL)          S1P19630
      IOCP     CLOCK+83,,2        WRITE                             S1P19640
      IOCP     CLOCK+87,,2        READ                              S1P19650
      IOCP     CLOCK+85,,2        WRITE                             S1P19660
      IOCD     CLOCK+89,,16       READ                              S1P19670
      PZE      *+10                                                 S1P19680
      PZE      *+9,,1000                                            S1P19690
      PZE      *+8,,2000                                            S1P19700
      PZE      *+7,,3000                                            S1P19710
      PZE      *+6,,4000                                            S1P19720
      PZE      *+5,,5000                                            S1P19730
      PZE      *+4,,6000                                            S1P19740
      PZE      *+3,,7000                                            S1P19750
      PZE      *+2,,8000                                            S1P19760
      PZE      *+1,,9000                                            S1P19770
      PZE      *+10                                                 S1P19780
      PZE      *+9,,100                                             S1P19790
      PZE      *+8,,200                                             S1P19800
      PZE      *+7,,300                                             S1P19810
      PZE      *+6,,400                                             S1P19820
      PZE      *+5,,500                                             S1P19830
      PZE      *+4,,600                                             S1P19840
```

```
       PZE     *+3,,700                                                 S1P19850
       PZE     *+2,,800                                                 S1P19860
       PZE     *+1,,900                                                 S1P19870
       PZE     *+10                                                     S1P19880
       PZE     *+9,,10                                                  S1P19890
       PZE     *+8,,20                                                  S1P19900
       PZE     *+7,,30                                                  S1P19910
       PZE     *+6,,40                                                  S1P19920
       PZE     *+5,,50                                                  S1P19930
       PZE     *+4,,60                                                  S1P19940
       PZE     *+3,,70                                                  S1P19950
       PZE     *+2,,80                                                  S1P19960
       PZE     *+1,,90                                                  S1P19970
       PZE                                                              S1P19980
       PZE     ,,1                                                      S1P19990
       PZE     ,,2                                                      S1P20000
       PZE     ,,3                                                      S1P20010
       PZE     ,,4                                                      S1P20020
       PZE     ,,5                                                      S1P20030
       PZE     ,,6                                                      S1P20040
       PZE     ,,7                                                      S1P20050
       PZE     ,,8                                                      S1P20060
       PZE     ,,9                                                      S1P20070
       BCI     8,000000000001000010000011000100000101000110000111       S1P20080
       BCI     8,001000001001001010001011001100001101001110001111       S1P20090
       BCI     8,010000010001010010010011010100010101010110010111       S1P20100
       BCI     8,011000011001011010011011011100011101011110011111       S1P20110
       BCI     8,100000100001100010100011100100100101100110100111       S1P20120
       BCI     8,101000101001101010101011101100101101101110101111       S1P20130
       BCI     8,110000110001110010110011110100110101110110110111       S1P20140
       BCI     8,111000111001111010111011111100111101111110111111       S1P20150
       PZE     *                                                        S1P20160
       PZE     *-1                                                      S1P20170
       PON     *-2,,4096                                                S1P20180
       PON     *-3                                                      S1P20190
       PZE     *-4,,7*4096                                              S1P20200
       PZE     *-5,,6*4096                                              S1P20210
       PZE     *-6,,5*4096                                              S1P20220
       PZE     *-7,,4*4096                                              S1P20230
```

```
        PZE     *-8,,3*4096                                        S1P20240
        PZE     *-9,,2*4096                                        S1P20250
        PZE     *-10,,1*4096                                       S1P20260
        END                                                        S1P20270
*      FAP                                                         S1P20280
        COUNT   170                                                S1P20290
*       SUBROUTINES RTAPE, WTAPE, BACK, AND RESET                  S1P20300
        ENTRY   WTAPE                                              S1P20310
        ENTRY   RTAPE                                              S1P20320
        ENTRY   REW                                                S1P20330
        ENTRY   BACK                                               S1P20340
        ENTRY   RESET                                              S1P20350
WTAPE   CLA     WRS                                                S1P20360
        STD     WRTP                                               S1P20370
        STZ     FLAG1      SET FLAG1 FOR WRITING                   S1P20380
        TRA     BEGIN                                              S1P20390
RTAPE   CLA     RDS                                                S1P20400
        STD     WRTP    READ,  NOT WRITE                           S1P20410
        STL     FLAG1    SET FOR READING                           S1P20420
BEGIN   SXA     AXT,1                                              S1P20430
        SXA     AXT+1,2                                            S1P20440
        STZ     FLAG    FIRSTT TIME THROUGH                        S1P20450
        CLA*    1,4                                                S1P20460
        STA     BSR                                                S1P20470
        ANA     MASK                                               S1P20480
        TZE     *+3                                                S1P20490
        STL     FLAG2   SET FLAG2 FOR CAANNEL A                    S1P20500
        TRA     *+2                                                S1P20510
        STZ     FLAG2    SET FLAG2 FOR CHANNEL B                   S1P20520
        NZT*    4,4    IS THIS A CHECK                             S1P20530
        TRA     WR      GO AND START A READ OR WRITE               S1P20540
CK      TZE     CKB     CHECK FOR REDUNDANCY.                      S1P20550
CKA     TCOA    *                                                  S1P20560
        TRCA    ERR                                                S1P20570
        TRA     AXT                                                S1P20580
CKB     TCOB    *                                                  S1P20590
        TRCB    ERR                                                S1P20600
        TRA     AXT                                                S1P20610
ERR     ZET     FLAG    TAPE ERROR.   IS THIS THE FIRST TIME       S1P20620
```

```
         TRA    BLNK     NO                                                    S1P20630
         STL    FLAG                                                           S1P20640
BSR      BSR    **                                                             S1P20650
WR       CLA*   3,4                                                            S1P20660
         STD    IOC       WORD COUNT                                           S1P20670
         ARS    18                                                             S1P20680
         SSM                                                                   S1P20690
         ADD    2,4                                                            S1P20700
         ADD    =1       BOTTOM OF ARRAY IN AC                                 S1P20710
         STA    IOC                                                            S1P20720
         CLA*   1,4                                                            S1P20730
         STA    WRTP        SET TAPE UNIT ADDRESS                              S1P20740
         ANA    TPNR     PICK OUT LAST DIGIT                                   S1P20750
         PAX    ,1    TAPE M.     M TO XR 1                                    S1P20760
         CLA    TPCNT+1,1                                                      S1P20770
         STA    LD1                                                            S1P20780
         STA    COMP                                                           S1P20790
         STA    STORE                                                          S1P20800
         PDX    ,2                                                             S1P20810
LD1      LDQ    **,2                                                           S1P20820
         ZET    FLAG       IF RERUN,  DONT BUMP COUNTERS                       S1P20830
         TRA    RERUN                                                          S1P20840
         SSP              NOT A BACKSPACE SO SIGN PLUS                         S1P20850
         ADD    ONE                                                            S1P20860
         PDX    ,2                                                             S1P20870
         STD    TPCNT+1,1                                                      S1P20880
         STA    TPCNT+1,1                                                      S1P20890
         ZET    FLAG1     IS IT,READ OR WRITE                                  S1P20900
         TRA    WR1   READ OPEARATION                                          S1P20910
         XCA         WRITE OPERATION.  MUST MAKE UP NEXT RECORD ID NR.         S1P20920
         ADD    ONE                                                            S1P20930
         ADD    =1                                                             S1P20940
STORE    STO    **,2   STORE NEXT RECORD ID WORD IN TABLE                      S1P20950
         STO    IDENT     FIRST WORD OF RECORD                                 S1P20960
WR1      NZT    FLAG2   CHANNEL A OR B                                         S1P20970
         TRA    TPB                                                            S1P20980
TPA      TCOA   *                                                              S1P20990
         TRCA   *+1                                                            S1P21000
         XEC    WRTP                                                           S1P21010
```

```
         RCHA     ICID                                                    S1P21020
         LCHA     IOC                                                     S1P21030
         ZET      FLAG1     IF READING,  GO CHECK RECORD ID               S1P21040
         TRA      COMP                                                    S1P21050
         ZET      FLAG    IS THIS A RERUN                                 S1P21060
         TRA      CKA   YES.  GO AND CHECK FOR REDUNDANCY                 S1P21070
         TRA      AXT    NO.  GO BACK AND COMPUTE SOME MORE               S1P21080
TPB      TCOB     *                                                       S1P21090
         TRCB     *+1                                                     S1P21100
         XEC      WRTP                                                    S1P21110
         RCHB     ICID                                                    S1P21120
         LCHB     IOC                                                     S1P21130
         ZET      FLAG1                                                   S1P21140
         TRA      COMP                                                    S1P21150
         ZET      FLAG                                                    S1P21160
         TRA      CKB                                                     S1P21170
         TRA      AXT                                                     S1P21180
COMP     CLA      **,2                                                    S1P21190
         SUB      IDENT    DOES FIRST WORD OF RECORD AGREE WITH ID        S1P21200
         TNZ      SHIFT    NO.   TRY ANOTHER RECORD                       S1P21210
         STP      TPCNT+1,1                                               S1P21220
         NZT      FLAG    YES.  IS THIS A RERUN                           S1P21230
         TRA      AXT     IF NOT,  GO BACK                                S1P21240
         CLA      FLAG2                                                   S1P21250
         TRA      CK                                                      S1P21260
RERUN    ZET      FLAG1                                                   S1P21270
         TRA      WR1                                                     S1P21280
         XCA          RESET ID WORD                                       S1P21290
         TRA      STORE+1                                                 S1P21300
BLNK     ZET      FLAG1   IS THIS A READ                                  S1P21310
         TRA      OUT   IF SO GIVE UP                                     S1P21320
         XEC      BSR                                                     S1P21330
         XEC      WRTP                                                    S1P21340
         XEC      WRTP                                                    S1P21350
         XEC      WRTP                                                    S1P21360
         CLA      MAX                                                     S1P21370
         SUB      =1                                                      S1P21380
         TMI      OUT   QUIT AFTER MAX TIMES                              S1P21390
         STO      MAX                                                     S1P21400
```

```
         CLA    IDENT                                                      S1P21410
         TRA    STORE-1                                                    S1P21420
SHIFT    CLA    MAX                                                        S1P21430
         SUB    =1                                                         S1P21440
         TMI    OUT                                                        S1P21450
         STO    MAX                                                        S1P21460
         CLA    TPCNT+1,1                                                  S1P21470
         TPL    WR1   LAST ACTIVITY WAS READ OR WRITE SO GO AHEAD          S1P21480
         XEC    BSR    LAST ACTIVITY WAS BACKSPACE.  MUST GO BACK          S1P21490
         XEC    BSR                                                        S1P21500
         TRA    WR1   LOOK FOR MISSING RECORD AGAIN                        S1P21510
AXT      AXT    **,1                                                       S1P21520
         AXT    **,2                                                       S1P21530
         TRA    5,4                                                        S1P21540
OUT      CALL   DUMP                                                       S1P21550
REW      CLA*   1,4                                                        S1P21560
         STA    *+1                                                        S1P21570
         REW    **                                                         S1P21580
         SXA    AX,1                                                       S1P21590
         ANA    TPNR                                                       S1P21600
         PAX    ,1                                                         S1P21610
         PXA    0,0                                                        S1P21620
         STD    TPCNT+1,1                                                  S1P21630
AX       AXT    **,1                                                       S1P21640
         TRA    2,4                                                        S1P21650
BACK     CLA*   1,4                                                        S1P21660
         STA    BSR                                                        S1P21670
         XEC    BSR                                                        S1P21680
         SXA    BX,1                                                       S1P21690
         ANA    TPNR                                                       S1P21700
         PAX    ,1                                                         S1P21710
         CLA    TPCNT+1,1                                                  S1P21720
         SSP                                                               S1P21730
         SUB    ONE                                                        S1P21740
         SSM                                                               S1P21750
         STO    TPCNT+1,1                                                  S1P21760
BX       AXT    ,1                                                         S1P21770
         TRA    2,4                                                        S1P21780
         NOP                                                               S1P21790
```

```
RESET   PXA     0,0                                                     S1P21800
        STD     TPCNT-3                                                 S1P21810
        STD     TPCNT-2                                                 S1P21820
        STD     TPCNT-1                                                 S1P21830
        STD     TPCNT                                                   S1P21840
        TPA     1,4                                                     S1P21850
ICID    IOST    IDENT,,1                                                S1P21860
IOC     IORT    0,,0                                                    S1P21870
WRTP    WRS     **                                                      S1P21880
WRS     WRS     **                                                      S1P21890
RDS     RDS     **                                                      S1P21900
        PZE     TBL4                                                    S1P21910
        PZE     TBL3                                                    S1P21920
                TBL2                                                    S1P21930
TPCNT           TBL1                                                    S1P21940
TPNR    OCT     7                                                       S1P21950
MASK    OCT     000000001000                                            S1P21960
MAX     DEC     40                                                      S1P21970
ONE     OCT     1000000                                                 S1P21980
FLAG                                                                    S1P21990
FLAG1                                                                   S1P22000
FLAG2                                                                   S1P22010
IDENT   PZE                                                             S1P22020
TBL1    BES     80                                                      S1P22030
TBL2    BES     80                                                      S1P22040
TBL3    BES     80                                                      S1P22050
TBL4    BES     80                                                      S1P22060
                                                                        S1P22070
        END                                                             S1P22080
*     CHAIN(2,2)                                                        S1P22090
*     FORTRAN                                                           S1P22100
CS1TWO      CHAIN LINK 2 FOR SPHERE                                     S1P22110
      COMMON IOPT1, IOPT2, IOPT3, IOPT4, IOPT5, IOPT6, IOPT7, IOPT8     S1P22120
      COMMON NCF                                                        S1P22130
      COMMON NDIM, NROW, NCOL, MM, MFLAG, XM,XLD                        S1P22140

      COMMON ISW1, ISW2, ISW3                                           S1P22150
      COMMON A                                                          S1P22160
      COMMON  TMP, YK, YL                                               S1P22170
      COMMON T1, T2, XX, XX1, Z, Z1, Z2                                 S1P22180
```

```
      COMMON ZNU, THC, PH1, FF, RH, DD, XH, XK                          S1P22190
      COMMON ZETA                                                       S1P22200
      COMMON TE, TI, TO, OC, TC, TD, DDLD                               S1P22210
      COMMON RECORD                                                     S1P22220
      DIMENSION A(1232)                                                 S1P22230
      DIMENSION MM(40)                                                  S1P22240
      DIMENSION T1( 89), T2(89), XX(89), XX1(89), Z(89), Z1(89), Z2(89) S1P22250
      DIMENSION TMP(5184), YK(5184), YL(4,4,324)                        S1P22260
      DIMENSION ZETA (30)                                               S1P22270
      DIMENSION RECORD (12)                                             S1P22280
      DIMENSION DISP(9), STRSS(9), ORDLBL(6,11),ABLBL(6), CILBL(6,4)    S1P22290
      DIMENSION ABSC(80), AORD(25), BOND(9)                             S1P22300
      DIMENSION CBLBL (6, 4)                                            S1P22310
      DIMENSION AXLBL (6)                                               S1P22320
    1 FORMAT (1H1, 12A6)                                                S1P22330
  966 FORMAT (6A6)                                                      S1P22340
B     XXN=255151606060                                                  S1P22350
      KTAPE=15                                                          S1P22360
      MO=1-IOPT2                                                        S1P22370
      NR1=NROW+1                                                        S1P22380
      NC1=NCOL+1                                                        S1P22390
      NR3=3*(NROW+6)                                                    S1P22400
      NR4=NR1+1-MO                                                      S1P22410
   51 READ INPUT TAPE 5, 966,((CILBL(I, J),I=1, 6), J=1, 4)             S1P22420
      NEND=0                                                            S1P22430
      NCRV=MM(31)                                                       S1P22440
      NCRV1=2-MO                                                        S1P22450
      NPTS=NCOL/26+1                                                    S1P22460
      NFLAG=1                                                           S1P22470
      CALL PLTLBL (DISP, STRSS, ORDLBL, ABLBL, BOND, AXLBL)             S1P22480
      TH=0.                                                             S1P22490
      COL=NCOL                                                          S1P22500
      DELH=1./COL                                                       S1P22510
      DO 52 I=1, NC1                                                    S1P22520
      ABSC(I)=TH                                                        S1P22530
   52 TH=TH+DELH                                                        S1P22540
      DO 53 J=1, NR1                                                    S1P22550
      JJ=NR1+2-J                                                        S1P22560
   53 AORD(J)=ZETA(JJ)                                                  S1P22570
```

```
      AORD(NR1+1)=ZETA(1)                                               S1P22580
  601 DO 650 K=1,3                                                      S1P22590
      WRITE TAPE KTAPE, RECORD                                          S1P22600
      WRITE TAPE KTAPE, NC1, NCRV, NPTS, NEND, NFLAG                    S1P22610
      WRITE TAPE KTAPE, ABLBL,  (ORDLBL(M,K),M=1,6), DISP               S1P22620
      WRITE TAPE KTAPE, CILBL                                           S1P22630
      DO 610 I=1, NC1                                                   S1P22640
      WRITE TAPE KTAPE, ABSC(I)                                         S1P22650
  610 CONTINUE                                                          S1P22660
      L=32                                                              S1P22670
      L3=31+MM(31)                                                      S1P22680
      DO 620 J=0, NR1                                                   S1P22690
      IF (MM(L)-J) 620, 611, 620                                        S1P22700
  611 I1=3*(J+2)+K                                                      S1P22710
      DO 615 I=1, NC1                                                   S1P22720
      WRITE TAPE KTAPE, TMP(I1)                                         S1P22730
  615 I1=I1+NR3                                                         S1P22740
      L=L+1                                                             S1P22750
      IF (L-L3) 620, 620, 650                                           S1P22760
  620 CONTINUE                                                          S1P22770
  650 CONTINUE                                                          S1P22780
      DO 720 K=1, 4                                                     S1P22790
      K1=K+3                                                            S1P22800
      WRITE TAPE KTAPE, RECORD                                          S1P22810
      WRITE TAPE KTAPE, NC1, NCRV, NPTS, NEND, NFLAG                    S1P22820
      WRITE TAPE KTAPE, ABLBL, (ORDLBL(M, K1), M=1, 6), STRSS           S1P22830
      WRITE TAPE KTAPE, CILBL                                           S1P22840
      DO 662 I=1, NC1                                                   S1P22850
      WRITE TAPE KTAPE, ABSC(I)                                         S1P22860
  662 CONTINUE                                                          S1P22870
      DO 660 M=1, NCRV                                                  S1P22880
      DO 660 I=1, NC1                                                   S1P22890
  660 WRITE TAPE KTAPE, YL(K,M,I)                                       S1P22900
  720 CONTINUE                                                          S1P22910
      DO 740 K1=1, 4                                                    S1P22920
      K=K1+7                                                            S1P22930
      NCRV=NCRV1                                                        S1P22940
      NCR=0                                                             S1P22950
      NCX=NC1                                                           S1P22960
```

```
  725 WRITE TAPE KTAPE, RECORD                                      S1P22970
      WRITE TAPE KTAPE, NCX, NCRV, NPTS, NEND, NFLAG                S1P22980
      IF (NCR) 723, 723, 724                                        S1P22990
  723 CONTINUE                                                      S1P23000
      WRITE TAPE KTAPE, ABLBL, (ORDLBL(M,K), M=1, 6), BOND          S1P23010
      GO TO 726                                                     S1P23020
  724 CONTINUE                                                      S1P23030
      WRITE TAPE KTAPE, AXLBL, (ORDLBL(M, K), M=1, 6), BOND         S1P23040
  726 CONTINUE                                                      S1P23050
      CALL PLBL (CBLBL, NCR)                                        S1P23060
      WRITE TAPE KTAPE, CBLBL                                       S1P23070
      IF (NCR) 727, 727, 729                                        S1P23080
  727 DO 728 I=1, NC1                                               S1P23090
  728 WRITE TAPE KTAPE, ABSC(I)                                     S1P23100
      I1=K1                                                         S1P23110
      GO TO 731                                                     S1P23120
  729 DO 730 I=1, NR4                                               S1P23130
  730 WRITE TAPE KTAPE, AORD(I)                                     S1P23140
  731 CONTINUE                                                      S1P23150
      KAD=4                                                         S1P23160
      DO 735 M=1, NCRV                                              S1P23170
      DO 732 L=1, NCX                                               S1P23180
      WRITE TAPE KTAPE, YK(I1)                                      S1P23190
  732 I1=I1+KAD                                                     S1P23200
      I1=4*(NC1+NC1+NR1)+K1                                         S1P23210
  735 KAD=-4                                                        S1P23220
      IF (NCR) 736, 736, 740                                        S1P23230
  736 NCR=1                                                         S1P23240
      I1=4*NC1+K1                                                   S1P23250
      KAD=4                                                         S1P23260
      NCX=NR4                                                       S1P23270
      NCRV=1                                                        S1P23280
      IF (K1-4) 715, 714, 714                                       S1P23290
  714 NEND=1                                                        S1P23300
  715 CONTINUE                                                      S1P23310
      GO TO 725                                                     S1P23320
  740 CONTINUE                                                      S1P23330
      WRITE TAPE KTAPE, XXN                                         S1P23340
      BACKSPACE KTAPE                                               S1P23350
```

```
      IF (IOPT5) 1010, 1010, 1011                                      S1P23360
 1010 CALL CHAIN (1, 2)                                                S1P23370
 1011 CALL CHAIN (3,2)                                                 S1P23380
      END                                                              S1P23390
*     FAP                                                              S1P23400
        COUNT    80                                                    S1P23410
*PLTLBL  SUBROUTINE PLTLBL (DISP, STRSS, ORDLBL, ABLBL, BOND )         S1P23420
        ENTRY    PLTLBL                                                S1P23430
PLTLBL  SXA      AXT,1                                                 S1P23440
        SXA      AXT+1,2                                               S1P23450
        CLA      1,4                                                   S1P23460
        STA      D1+1                                                  S1P23470
        AXT      9,1                                                   S1P23480
        AXT      0,2                                                   S1P23490
D1      CLA      DISP+9,1                                              S1P23500
        STO      **,2                                                  S1P23510
        TNX      *+2,1,1                                               S1P23520
        TXI      D1,2,1                                                S1P23530
        CLA      2,4                                                   S1P23540
        STA      S1+1                                                  S1P23550
        AXT      9,1                                                   S1P23560
        AXT      0,2                                                   S1P23570
S1      CLA      STRSS+9,1                                             S1P23580
        STO      **,2                                                  S1P23590
        TNX      *+2,1,1                                               S1P23600
        TXI      S1,2,1                                                S1P23610
        CLA      3,4                                                   S1P23620
        STA      O1+1                                                  S1P23630
        AXT      66,1                                                  S1P23640
        AXT      0,2                                                   S1P23650
O1      CLA      ORDU+66,1                                             S1P23660
        STO      **,2                                                  S1P23670
        TNX      *+2,1,1                                               S1P23680
        TXI      O1,2,1                                                S1P23690
        CLA      4,4                                                   S1P23700
        STA      A1+1                                                  S1P23710
        AXT      6,1                                                   S1P23720
        AXT      0,2                                                   S1P23730
A1      CLA      ABLBL+6,1                                             S1P23740
```

```
         STO    **,2                                            S1P23750
         TNX    *+2,1,1                                         S1P23760
         TXI    A1,2,1                                          S1P23770
         CLA    5,4                                             S1P23780
         STA    B1+1                                            S1P23790
         AXT    9,1                                             S1P23800
         AXT    0,2                                             S1P23810
B1       CLA    BON+9,1                                         S1P23820
         STO    **,2                                            S1P23830
         TNX    *+2,1,1                                         S1P23840
         TXI    B1,2,1                                          S1P23850
         CLA    6,4                                             S1P23860
         STA    AX1+1                                           S1P23870
         AXT    6,1                                             S1P23880
         AXT    0,2                                             S1P23890
AX1      CLA    AXLBL+6,1                                       S1P23900
         STO    **,2                                            S1P23910
         TNX    *+2,1,1                                         S1P23920
         TXI    AX1,2,1                                         S1P23930
AXT      AXT    **,1                                            S1P23940
         AXT    **,2                                            S1P23950
         TRA    7,4                                             S1P23960
ORDU     BCI    6,           U                                  S1P23970
ORDV     BCI    6,           V                                  S1P23980
ORDW     BCI    6,           W                                  S1P23990
ORDNX    BCI    6,            NPHI                              S1P24000
ORDNT    BCI    6,            NTHETA                            S1P24010
ORDMX    BCI    6,            MPHI                              S1P24020
ORDMT    BCI    6,            MTHETA                            S1P24030
ORDN     BCI    6,        NTAN                                  S1P24040
ORDNB    BCI    6,        NNORM                                 S1P24050
ORDQ     BCI    6,          Q                                   S1P24060
ORDM     BCI    6,          M                                   S1P24070
ABLBL    BCI    6,         THETA                                S1P24080
AXLBL    BCI    6,           PHI                                S1P24090
DISP     BCI    9,      FIG.     SPHERE DISPLACEMENT COMPONENTS S1P24100
STRSS    BCI    9,      FIG.     SPHERE STRESS RESULTANTS       S1P24110
BON      BCI    9,      FIG.     BOUNDARY STRESS RESULTANTS     S1P24120
         END                                                    S1P24130
```

```
*      FAP                                                           S1P24140
        COUNT    40                                                  S1P24150
*PLBL    SUBROUTINE PLBL (CBLBL, NCR)                                S1P24160
        ENTRY    PLBL                                                S1P24170
PLBL    SXA      AXT,1                                               S1P24180
        SXA      AXT+1,2                                             S1P24190
        NZT*     2,4                                                 S1P24200
        TRA      UPPER                                               S1P24210
RIGT    CLA      1,4                                                 S1P24220
        STA      R1+1                                                S1P24230
        AXT      6,1                                                 S1P24240
        AXT      0,2                                                 S1P24250
R1      CLA.     RT+6,1                                              S1P24260
        STO      **,2                                                S1P24270
        TNX      AXT,1,1                                             S1P24280
        TXI      R1,2,1                                              S1P24290
UPPER   CLA      1,4                                                 S1P24300
        STA      UP+1                                                S1P24310
        AXT      12,1                                                S1P24320
        AXT      0,2                                                 S1P24330
UP      CLA      UPP+12,1                                            S1P24340
        STO      **,2                                                S1P24350
        TNX      AXT,1,1                                             S1P24360
        TXI      UP,2,1                                              S1P24370
AXT     AXT      **,1                                                S1P24380
        AXT      **,2                                                S1P24390
        TRA      3,4                                                 S1P24400
RT      BCI      6,    RIGHT BOUNDARY                                S1P24410
UPP     BCI      6,    CURVE 1= UPPER BOUNDARY                       S1P24420
        BCI      6,    CURVE 2= LOWER  BOUNDARY                      S1P24430
        END                                                          S1P24440
*      CHAIN(3,2)                                                    S1P24450
*      FORTRAN                                                       S1P24460
C      INDEX (1270)                                                  S1P24470
C      PROGRAM TO CONTROL PLOTTING FROM SCRATCH TAPE                 S1P24480
C      CAN PLOT SEQUENTIAL GRAPHS EACH HAVING SEVERAL CURVES         S1P24490
C      NXP = NUMBER OF VALUES OF INDEPENDENT VARIABLE FOR A GIVEN GRAPH  S1P24500
C      NCRVS = NUMBER OF CURVES TO BE PLOTTED ON A GIVEN GRAPH       S1P24510
C      NPTS = NUMBER OF INTERVALS BETWEEN DEPENDENT VARIABLE VALUES  S1P24520
```

```
C       AT WHICH IDENTIFYING SYMBOLS ARE TO BE PLACED                   S1P24530
C       IF NEND = 0, OTHER GRAPHS ARE TO FOLLOW                         S1P24540
C       IF NEND = 1, CURRENT GRAPH IS THE LAST                          S1P24550
C       IF NFLAG = 0, CONTROL WILL BE RETURNED TO CHAIN (1,3)           S1P24560
C       IF NFLAG = 1, RUN WILL BE TERMINATED BY CALL EXIT               S1P24570
        DIMENSION XP(200),YP(200,4),ABLBL(6),ORDLBL(6),GPHLBL(9),       S1P24580
      1 CILBL(6,4),RECORD(12),YT(200)                                   S1P24590
        EQUIVALENCE (KR,ER), (XXN, NERR)                                S1P24600
        KP=15                                                           S1P24610
        REWIND KP                                                       S1P24620
B       XXN=255151606060                                                S1P24630
        NEND=0                                                          S1P24640
     20 READ TAPE KP, RECORD                                            S1P24650
        READ TAPE KP, NXP, NCRVS, NPTS, NEND, NFLAG                     S1P24660
        READ TAPE KP, ABLBL, ORDLBL, GPHLBL                             S1P24670
        READ TAPE KP, CILBL                                             S1P24680
        DO 32 KT = 1,NXP                                                S1P24690
     32 READ TAPE KP, XP(KT)                                            S1P24700
        DO 33 L = 1,NCRVS                                               S1P24710
        DO 33 KT = 1,NXP                                                S1P24720
        READ TAPE KP, YT(KT)                                            S1P24730
     33 YP(KT,L) = YT(KT)                                               S1P24740
        READ TAPE KP,ER                                                 S1P24750
        BACKSPACE KP                                                    S1P24760
        IF (KR-NERR) 61, 60, 61                                         S1P24770
     60 NEND=1                                                          S1P24780
     61 CONTINUE                                                        S1P24790
        CALL PLOTS(NXP,NCRVS,NPTS,NEND,NFLAG,XP,YP,RECORD,ABLBL,ORDLBL, S1P24800
      1 GPHLBL,CILBL)                                                   S1P24810
        IF(NEND)20,20,21                                                S1P24820
     21 IF(NFLAG)40,40,41                                               S1P24830
     40 CALL CHAIN (1,2)                                                S1P24840
     41 CALL EXIT                                                       S1P24850
        END                                                             S1P24860
*       FORTRAN                                                         S1P24870
        SUBROUTINE PLOTS(NXP,NCRVS,NPTS,NEND,NFLAG,X,Y,RECORD,ABLBL,    S1P24880
      1 ORDLBL,GPHLBL,CILBL)                                            S1P24890
C       SC 4020 ROUTINE FOR PLOTTING SEVERAL CURVES ON A SINGLE GRAPH   S1P24900
C       INDEX (1280)                                                    S1P24910
```

```
      DIMENSION X(200),Y(200,4),ABLBL(6),ORDLBL(6), GPHLBL(9),RECORD(12)S1P24920
      DIMENSION KX1(4),KY1(4),KX2(4),CILBL(6,4),CLBL(6),                S1P24930
     1 ORDL(6),GPHL(6),YP(200),MRK(4)                                   S1P24940
      WRITE OUTPUT TAPE 6,10                                            S1P24950
   10 FORMAT(15H0  PLOT CALLED       )                                  S1P24960
F     TABL1V                                                            S1P24970
      CALL CAMRAV(9)                                                    S1P24980
      XL = X(1)                                                         S1P24990
      XR = X(1)                                                         S1P25000
      DO 20 I = 2,NXP                                                   S1P25010
      XL = MIN1F(XL,X(I))                                               S1P25020
   20 XR = MAX1F(XR,X(I))                                               S1P25030
      DC = 20.0                                                         S1P25040
      CALL DXDYV(1,XL,XR,DX,N,II,NX,DC,IERR)                            S1P25050
      KX1(1) = 185                                                      S1P25060
      KX1(2) = 185                                                      S1P25070
      KX1(3) = 585                                                      S1P25080
      KX1(4) = 585                                                      S1P25090
      KY1(1) = 985                                                      S1P25100
      KY1(2) = 955                                                      S1P25110
      KY1(3) = 985                                                      S1P25120
      KY1(4) = 955                                                      S1P25130
      KX2(1) = 200                                                      S1P25140
      KX2(2) = 200                                                      S1P25150
      KX2(3) = 600                                                      S1P25160
      KX2(4) = 600                                                      S1P25170
      MRK(1) = 38                                                       S1P25180
      MRK(2) = 55                                                       S1P25190
      MRK(3) = 63                                                       S1P25200
      MRK(4) = 53                                                       S1P25210
      YB = 0.0                                                          S1P25220
      YT = 0.0                                                          S1P25230
      DO 40 J = 1,NCRVS                                                 S1P25240
      DO 40 I = 2,NXP                                                   S1P25250
      YB = MIN1F(YB,Y(I,J))                                             S1P25260
   40 YT = MAX1F(YT,Y(I,J))                                             S1P25270
      YB = YB*1.10                                                      S1P25280
      YT = YT*1.10                                                      S1P25290
      L = 1                                                             S1P25300
```

```
      CALL DXDYV(2,YB,YT,DY,M,JJ,NY,DC,IERR1)                           S1P25310
      NX = + 3                                                          S1P25320
      NY=-2                                                             S1P25330
      II = -II                                                          S1P25340
      JJ = -JJ                                                          S1P25350
      CALL SETMIV(100,10,70,100)                                        S1P25360
      CALL GRID1V(L,XL,XR,YB,YT,DX,DY,N,M,II,JJ,NX,NY)                  S1P25370
      DO 60 K = 1,6                                                     S1P25380
   60 ORDL(K) = ORDLBL(K)                                               S1P25390
      CALL CHSIZV(2,2)                                                  S1P25400
      CALL RITSTV(12,18,TABL1V)                                         S1P25410
      CALL RITE2V(75,330,1023,180,1,36,1,ORDL,NLAST)                    S1P25420
      CALL RITE2V(330,57,1023,90,1,36,1,ABLBL,NLAST)                    S1P25430
      CALL PRINTV(72,RECORD,100,1015)                                   S1P25440
      DO 61 K = 1,9                                                     S1P25450
   61 GPHL(K) = GPHLBL(K)                                               S1P25460
      CALL CHSIZV(3,4)                                                  S1P25470
      CALL RITSTV(18,30,TABL1V)                                         S1P25480
      CALL RITE2V(40,20,1023,90,2,54,1,GPHL,NLAST )                     S1P25490
      DO 70 J = 1,NCRVS                                                 S1P25500
      YP(1) = Y(1,J)                                                    S1P25510
      NX1 = NXV(X(1))                                                   S1P25520
      NY1 = NYV(YP(1))                                                  S1P25530
      DO 50 I = 1,NXP                                                   S1P25540
      YP(I) = Y(I,J)                                                    S1P25550
      NX2 = NXV(X(I))                                                   S1P25560
      NY2 = NYV(YP(I))                                                  S1P25570
      IF(NX2*NY2)45,50,45                                               S1P25580
   45 CALL LINEV(NX1,NY1,NX2,NY2)                                       S1P25590
      NX1 = NX2                                                         S1P25600
      NY1 = NY2                                                         S1P25610
   50 CONTINUE                                                          S1P25620
      MRKPT = MRK(J)                                                    S1P25630
      CALL APLOTV(NXP,X,YP,NPTS,NPTS,1,MRKPT,IERR)                      S1P25640
      KX = KX1(J)                                                       S1P25650
      KY = KY1(J)                                                       S1P25660
      NS = J                                                            S1P25670
      CALL POINTV(KX,KY,NS,ANY)                                         S1P25680
      KXC = KX2(J)                                                      S1P25690
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      DO 93 K = 1,6                                              S1P25700
   93 CLBL(K) = CILBL(K,J)                                       S1P25710
   92 CALL PRINTV(36,CLBL,KXC,KY)                                S1P25720
   70 CONTINUE                                                   S1P25730
      IF(NEND)90,90,91                                           S1P25740
   91 CALL FOFTV                                                 S1P25750
      WRITE OUTPUT TAPE 6,80                                     S1P25760
   80 FORMAT(22H0  PLOTTING COMPLETED       )                    S1P25770
   90 RETURN                                                     S1P25780
      END                                                        S1P25790
```