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STUDY OF APOLLO WATER IMPACT
FINAL REPORT

VOLUME 10

USER'S MANUAL FOR MODIFICATION OF SHELL OF REVOLUTION ANALYSIS

(Contract NAS9-4552, G.O. 5264)

May 1967

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FOREWORD

This report was prepared by North American Aviation, Inc., Space Division, under NASA Contract NAS9-4552, for the National Aeronautics and Space Administration, Manned Space Flight Center, Houston, Texas, with Dr. F.C. Hung, Program Manager and Mr. P.P. Radkowski, Assistant Program Manager. This work was administered under the direction of Structural Mechanics Division, MSC, Houston, Texas with Dr. F. Stebbins as the technical monitor.

This report is presented in eleven volumes for convenience in handling and distribution. All volumes are unclassified.

The objective of the study was to develop methods and Fortran IV computer programs to determine by the techniques described below, the hydro-elastic response of representation of the structure of the Apollo Command Module immediately following impact on the water. The development of theory, methods and computer programs is presented as Task I Hydrodynamic Pressures, Task II Structural Response and Task III Hydroelastic Response Analysis.

Under Task I - Computing program to extend flexible sphere using the Spencer and Shiffman approach has been developed. Analytical formulation by Dr. Li using nonlinear hydrodynamic theory on structural portion is formulated. In order to cover a wide range of impact conditions, future extensions are necessary in the following items:

a. Using linear hydrodynamic theory to include horizontal velocity and rotation.

b. Nonlinear hydrodynamic theory to develop computing program on spherical portion and to develop nonlinear theory on toroidal and conic sections.

Under Task II - Computing program and User's Manual were developed for nonsymmetrical loading on unsymmetrical elastic shells. To fully develop the theory and methods to cover realistic Apollo configuration the following extensions are recommended:

a. Modes of vibration and modal analysis.

b. Extension to nonsymmetric short time impulses.

c. Linear buckling and elasto-plastic analysis

These technical extensions will not only be useful for Apollo and future Apollo growth configurations, but they will also be of value to other aeronautical and spacecraft programs.

The hydroelastic response of the flexible shell is obtained by the numerical solution of the combined hydrodynamic and shell equations. The results obtained herein are compared numerically with those derived by neglecting the interaction and applying rigid body pressures to the same elastic shell. The numerical results show that for an axially symmetric impact of the particular shell studied, the interaction between the shell and the fluid produces appreciable differences in the overall acceleration of the center of gravity of the shell, and in the distribution of the pressures and responses. However the maximum responses are within 15% of those produced when the interaction between the fluid and the shell is neglected. A brief summary of results is shown in the abstracts of individual volumes.

The volume number and authors are listed on the following page.

The contractor's designation for this report is SID 67-498.

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ABSTRACT

The shell of revolution program described in this report was developed as a basic tool to be used in the elastic, load-deflection analysis of shell structures subjected to arbitrary loads and temperatures. The program is applicable to most aerospace-type shell elements (e. g., boosters, reentry vehicles, etc.) as well as ground-based shells.

The computer program is based on the numerical analysis presented in Reference 1 and is restricted to linear-elastic thin-shell theory. The analysis utilizes Fourier series expansion technique to separate circumferential variation of problem variables. A reduced set of shell field equations for each Fourier harmonic of load results from using Fourier approach. The finite difference form of the reduced shell equations are solved by a direct matrix elimination procedure. Solutions for various Fourier harmonics can then be summed to obtain the general solution for arbitrary unsymmetric loads.

In using the program it is necessary to select a mathematical model to represent a physical shell problem. By introducing fictitious subdivisions called shell regions, it is possible to analyse complicated shell configurations as a series of shell regions of simple shapes. The procedures for connecting shell regions require the satisfaction of boundary and junction conditions in the program.

The computer program,which was written in FORTRAN IV and applicable to the IBM 7090/7094 systems, was developed in a general fashion to permit the consideration of variety of shell problems. Wherever possible, time and space-saving techniques have been employed to simplify and reduce the amount of input data to be supplied by the user. Various option techniques have been used to permit more generality and still keep data input at a respectable minimum. The solutions obtained from the program yield deformations, forces, moments, stresses, etc., at each station of a shell region. This output is presented in tabular form with an option for graphical plotting of results.

The users of this program should be forewarned that the program is only a tool and considerable insight must be used in relating results to an actual physical shell problem. In turn, the results obtained are only as good as the mathematical model selected for the problem. The numerical procedure used in the solution of differential shell equations is an approximate one

(finite differences) and results must be interpreted in terms of round-off errors that are inevitable when using approximate numerical techniques.

This report is intended to supply the information necessary for the best utilization of the shell of revolution computer program. Considerable detail has been incorporated in this report to aid not only the engineer but also the programmer in understanding the program. It is hoped that this information will permit the modification and extension of this program to handle various other types of shell response problems (e. g., dynamics, buckling, etc.).

This user's manual has been organized in three basic sections. The first section (I) presents the theory used as a basis of the shell of revolution computer program. For ease of reference, much of the numerical procedure developed in Reference 1 is repeated together with modifications and improvements that have been developed at S&ID. A general description of the computer program is given in Section II. This section is intended to serve as an aid to the user in establishing a mathematical model for a physical shell problem in terms of the program format. Limitations and general program characteristics are given. Section III gives information for the detailed use of the program. Included are input data shell format, flow diagrams, sample data sheets, example problem, etc. As one becomes familiar with the program, this section will probably be the most used since it gives detailed instructions and characteristics of the program.

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I. THEORY

1.1 INTRODUCTION

The general numerical procedure developed in Reference 1 for the analysis of unsymmetrical bending of shells of revolution forms the basis of the computer program. Included in the program are extensions and improvements to the basic analysis that were developed at S&ID and are reported in References 2 and 3.

The analysis is based on the general first-order linear shell theory of Sanders (Reference 4), which has been assessed (Reference 5) as the "best" of the many competing thin-shell theories in the literature. All pertinent variables are expanded into Fourier series in the circumferential direction which permit decoupled sets of ordinary differential equations in terms of the individual Fourier components. Finite difference approximations to these differential equations in the meridional coordinate then are solved using a direct matrix elimination technique (Potter's Method) (Reference 6).

This section will present the general theory which forms the basis of the computer program. Nomenclature and approach similar to that of Reference 1 will be used together with appropriate modifications.

1.2 SCOPE AND LIMITATIONS OF THEORY

The shell theory on which the program is based is restricted to linear, elastic, thin-shell theory. Implied by the above statement and other assumptions introduced in the analysis are the following:

a. The thickness of the shell at any point is small compared to the other dimensions of the shell.

b. Deformations of the shell are small compared to the dimensions of the shell.

c. All portions of the shell deform elastically, obeying Hooke's law.

d. The shell is "complete" as well as axisymmetric, i.e., its only boundaries are at meridian ends and inner and outer surfaces.

e. Each layer of shell material is assumed to have two-dimensional elastic isotropy with respect to the axes tangent to its surface, but Young's modulus is permitted to be variable (and discontinuous) through the thickness as well as in the meriodional direction.

f. Poisson's ratio is assumed constant in each shell layer.

g. Arbitrary loads and temperature distributions are permissible. However, the present analysis is inapplicable when circumferential variation of temperature is sufficiently great to produce appreciable circumferential changes in Young's modulus. In such cases, average values of Young's modulus can be used to obtain approximate results.

h. Redundant shell structures can be analysed only indirectly using the program.

i. The effects of transverse shear distortion are neglected in the analysis. A procedure for including these effects is described in Reference 7.

j. Instability is not considered.

1.3 SURFACE GEOMETRY AND COORDINATES

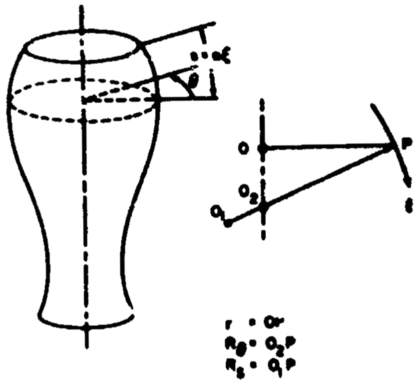


Figure 1-1. Surface Geometry and Coordinates

Material points in the shell can be specified by means of the orthogonal coordinates (s, θ , ζ), (see Figure 1-1) where s is the meridional distance measured from a boundary along an axisymmetric reference surface, θ is the circumferential angle, and ζ is the normal, outward distance from the reference surface. In homogeneous shells, the middle surface always is used as the reference surface; but when, more generally, the Young's modulus E is variable, the reference surface is best chosen so that

$$\int \zeta E \, d\zeta = 0 \qquad (1)$$

where the integration is through the thickness. (This choice, as will be seen later, simplifies the constitutive relations of elastic shells.) If the shape of the reference surface is given by $r(s)$, where r is the distance from the axis, the principal radii of curvature are

$$R_\theta = r\left|1 - (dr/ds)^2\right|^{-1/2}$$

$$R_s = -\left|1 - (dr/ds)^2\right|^{1/2}/(d^2r/ds^2) \qquad (2)$$

Introduce the nondimensional meriodional coordinate $\xi = s/a$, where a is a reference length; then, with $\rho = r/a$, the nondimensional curvatures $\omega_\xi = a/R_s$, and $\omega_\theta = a/R_\theta$ can be found from the formulas

$$\omega_\theta = \left|1 - (\rho')^2\right|^{1/2}/\rho \qquad (3)$$

$$\omega_\xi = -(\gamma' + \gamma^2)/\omega_\theta \qquad (4)$$

where

$$\gamma = \rho'/\rho \qquad (5)$$

In these equations, and henceforth, $(\ )' \equiv (d/d\xi)(\ )$. Finally, note the Codazzi identity

$$\omega_\theta' = \gamma(\omega_\xi - \omega_\theta) \qquad (6)$$

and the relation

$$\rho''/\rho = -\omega_\xi\,\omega_\theta \qquad (7)$$

1.4 EQUILIBRIUM EQUATIONS

The components of membrane force per unit length, transverse force per unit length, moment (about the reference surface) per unit length, and load per unit area (assumed to be applied at the reference surface) are as shown in Figure 1-2.

Figure 1-2. Forces, Moments, and Loads: a) Membrane Forces per Unit Length, b) Transverse Forces per Unit Length, c) Moments per Unit Length, d) Loads per Unit Area

In the Sanders theory, the shearing forces $N_{\xi\theta}$ and $N_{\theta\xi}$, as well as the twisting moments $M_{\xi\theta}$ and $M_{\theta\xi}$, are not handled separately but are combined to provide the modified variables

$$\bar{N}_{\xi\theta} = \frac{1}{2}(N_{\xi\theta} + N_{\theta\xi}) + \frac{1}{4}\left(\frac{1}{R_\theta} - \frac{1}{R_\xi}\right)(M_{\xi\theta} - M_{\theta\xi}) \tag{8}$$

and

$$\bar{M}_{\xi\theta} = \frac{1}{2}(M_{\xi\theta} + M_{\theta\xi}) \tag{9}$$

With the elimination of the transverse forces Q_ξ and Q_θ, the equilibrium equations of the Sanders theory (reference 4) can be written, for shells of revolution, as

$$a\left|\frac{\partial}{\partial\xi}(\rho N_\xi) + \frac{\partial}{\partial\theta}(\bar{N}_{\xi\theta}) - \rho' N_\theta\right| + \omega_\xi\left|\frac{\partial}{\partial\xi}(\rho M_\xi) + \frac{\partial}{\partial\theta}(\bar{M}_{\xi\theta}) - \rho' M_\theta\right| + \frac{1}{2}(\omega_\xi - \omega_\theta)\frac{\partial}{\partial\theta}(\bar{M}_{\xi\theta}) + a^2\rho q_\xi = 0 \tag{10a}$$

$$a\left|\frac{\partial}{\partial\theta}(N_\theta) + \frac{\partial}{\partial\xi}(\rho\bar{N}_{\xi\theta}) + \rho'\bar{N}_{\xi\theta}\right| + \omega_\theta\left|\frac{\partial}{\partial\theta}(M_\theta) + \frac{\partial}{\partial\xi}(\rho\bar{M}_{\xi\theta}) + \rho'\bar{M}_{\xi\theta}\right| + \frac{\rho}{2}\frac{\partial}{\partial\xi}\left|(\omega_\theta - \omega_\xi)\bar{M}_{\xi\theta}\right| + a^2\rho q_\theta = 0 \tag{10b}$$

$$\frac{\partial}{\partial\xi}\left|\frac{\partial}{\partial\xi}(\rho M_\xi) + \frac{\partial}{\partial\theta}(\bar{M}_{\xi\theta}) - \rho' M_\theta\right| + \frac{1}{\rho}\frac{\partial}{\partial\theta}\left|\frac{\partial}{\partial\theta}(M_\theta) + \frac{\partial}{\partial\xi}(\rho\bar{M}_{\xi\theta}) + \rho'\bar{M}_{\xi\theta}\right| - a\rho(\omega_\xi N_\xi + \omega_\theta N_\theta) + a^2\rho q = 0 \tag{10c}$$

1.5 DISPLACEMENTS, ROTATIONS, AND STRAINS

The displacements and rotations of the reference surface (Figure 1-3) are related by the equations

$$\Phi_\xi = \frac{1}{a}\left[-\frac{\partial W}{\partial\xi} + \omega_\xi U_\xi\right] \tag{11}$$

$$\Phi_\theta = \frac{1}{a}\left[-\frac{1}{\rho}\frac{\partial W}{\partial\theta} + \omega_\theta U_\theta\right]$$

The membrane strains of the reference surface are given by

$$\epsilon_\xi = \frac{1}{a}\left[\frac{\partial U_\xi}{\partial\xi} + \omega_\xi W\right]$$

$$\epsilon_\theta = \frac{1}{a}\left[\frac{1}{\rho}\frac{\partial U_\theta}{\partial\theta} + \gamma U_\xi + \omega_\theta W\right]$$

$$\epsilon_{\xi\theta} = \frac{1}{2a}\left[\frac{1}{\rho}\frac{\partial U_\xi}{\partial\theta} + \frac{\partial U_\theta}{\partial\xi} - \gamma U_\theta\right] \tag{12}$$

where $\epsilon_{\xi\theta}$ is half the usual engineering shear strain.

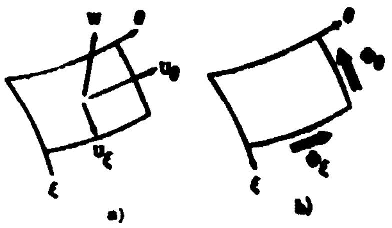


Figure 1-3. a) **Displacements**; b) Rotations

Finally, the measures of bending distortion used in the Sanders theory are

$$\kappa_\xi = \frac{1}{a}\frac{\partial \Phi_\xi}{\partial \xi}$$

$$\kappa_\theta = \frac{1}{a}\left[\frac{1}{\rho}\frac{\partial \Phi_\theta}{\partial \theta} + \gamma \Phi_\xi\right]$$

$$\kappa_{\xi\theta} = \frac{1}{2a}\left[\frac{1}{\rho}\frac{\partial \Phi_\xi}{\partial \theta} + \frac{\partial \Phi_\theta}{\partial \xi} - \gamma \Phi_\theta + \frac{1}{2a}(\omega_\xi - \omega_\theta)\left(\frac{1}{\rho}\frac{\partial U_\xi}{\partial \theta} - \frac{\partial U_\theta}{\partial \xi} - \gamma U_\theta\right)\right] \tag{13}$$

Then, by the usual Kirchhoff hypothesis ("normals remain normal") and the neglect of terms of order ζ/R_s and ζ/R_θ relative to unity,. the longitudinal, circumferential, and shear strains at a distance ζ from the reference surface are

$$\begin{aligned} &\epsilon_\xi + \zeta\kappa_\xi \\ &\epsilon_\theta + \zeta\kappa_\theta \\ &\epsilon_{\xi\theta} + \zeta\kappa_{\xi\theta} \end{aligned} \tag{14}$$

respectively.

1.6 CONSTITUTIVE RELATIONS

Neglecting, as usual, the effects of stresses normal to the shell permits the stress-strain-temperature relations to be written as

$$\begin{aligned}\epsilon_\xi + \zeta\kappa_\xi &= \left|(\sigma_\xi - \nu\sigma_\theta)/E\right| + \alpha T\\ \epsilon_\theta + \zeta\kappa_\theta &= \left|(\sigma_\theta - \nu\sigma_\xi)/E\right| + \alpha T\\ \epsilon_{\xi\theta} + \zeta\kappa_{\xi\theta} &= \left|(1+\nu)/E\right|\sigma_{\xi\theta}\end{aligned} \tag{15}$$

where the temperature change T may vary with ζ, as well as with ξ and θ. The Young's modulus E and the thermal expansion coefficient α will, however, be permitted to vary only with ξ and ζ. The (modified) forces and moments are approximated closely in the shell by the following integrals through the thickness:

$$\begin{aligned}N_\xi &= \int\sigma_\xi\,d\zeta & M_\xi &= \int\zeta\sigma_\xi\,d\zeta\\ N_\theta &= \int\sigma_\theta\,d\zeta & M_\theta &= \int\zeta\sigma_\theta\,d\zeta\\ \bar{N}_{\xi\theta} &= \int\sigma_{\xi\theta}\,d\zeta & \bar{M}_{\xi\theta} &= \int\zeta\sigma_{\xi\theta}\,d\zeta\end{aligned} \tag{16}$$

Then, with the use of the defining relation (Equation 1) for the reference surface, together with the assumption of constant Poisson's ratio, it is found from (Equations 14 through 16) that

$$\begin{aligned}\epsilon_\xi &= \frac{N_\xi - \nu N_\theta}{\int E\,d\zeta} + \frac{\int E\alpha T\,d\zeta}{\int E\,d\zeta}\\ \epsilon_\theta &= \frac{N_\theta - \nu N_\xi}{\int E\,d\zeta} + \frac{\int E\alpha T\,d\zeta}{\int E\,d\zeta}\\ \epsilon_{\xi\theta} &= \frac{(1+\nu)\bar{N}_{\xi\theta}}{\int E\,d\zeta}\end{aligned} \tag{17}$$

and

$$\begin{aligned}\kappa_\xi &= \frac{M_\xi - \nu M_\theta}{\int \zeta^2 E\,d\zeta} + \frac{\int\zeta E\alpha T\,d\zeta}{\int \zeta^2 E\,d\zeta}\\ \kappa_\theta &= \frac{M_\theta - \nu M_\xi}{\int \zeta^2 E\,d\zeta} + \frac{\int\zeta E\alpha T\,d\zeta}{\int \zeta^2 E\,d\zeta}\\ \kappa_{\xi\theta} &= \frac{(1+\nu)\bar{M}_{\xi\theta}}{\int \zeta^2 E\,d\zeta}\end{aligned} \tag{18}$$

The complete set of field equations for the 17 independent variables N_ξ, N_θ, $\overline{N}_{\xi\theta}$, M_ξ, M_θ, $\overline{M}_{\xi\theta}$, U_ξ, U_θ, W, Φ_ξ, Φ_θ, ϵ_ξ, ϵ_θ, $\epsilon_{\xi\theta}$, κ_ξ, κ_θ, $\kappa_{\xi\theta}$ now is given by the equations (10-13, 17, and 18).

1.7 FOURIER EXPANSIONS AND NONDIMENSIONAL EQUATIONS

The independent variables now will be expanded into Fourier series, with appropriate normalization to provide nondimensional Fourier coefficients of roughly comparable magnitudes for the different variables. Letting σ_0 be a reference stress level, E_0 a reference Young's modulus, and h_0 a reference thickness, solutions of the field equations will be sought in the following forms:

$$N_\xi = \sigma_0 h_0 \sum_{n=0}^{\infty} t_\xi^{(n)} \cos n\theta$$

$$N_\theta = \sigma_0 h_0 \sum_{n=0}^{\infty} t_\theta^{(n)} \cos n\theta$$

$$\overline{N}_{\xi\theta} = \sigma_0 h_0 \sum_{n=1}^{\infty} t_{\xi\theta}^{(n)} \sin n\theta \qquad (19)$$

$$M_\xi = \frac{\sigma_0 h_0{}^3}{a} \sum_{n=0}^{\infty} m_\xi^{(n)} \cos n\theta$$

$$M_\theta = \frac{\sigma_0 h_0{}^3}{a} \sum_{n=0}^{\infty} m_\theta^{(n)} \cos n\theta$$

$$\overline{M}_{\xi\theta} = \frac{\sigma_0 h_0{}^3}{a} \sum_{n=1}^{\infty} m_{\xi\theta}^{(n)} \sin n\theta \qquad (20)$$

$$U_\xi = \frac{a\sigma_0}{E_0} \sum_{n=0}^{\infty} u_\xi^{(n)} \cos n\theta$$

$$U_\theta = \frac{a\sigma_0}{E_0} \sum_{n=1}^{\infty} u_\theta^{(n)} \sin n\theta$$

$$W = \frac{a\sigma_0}{E_0} \sum_{n=0}^{\infty} w^{(n)} \cos n\theta \qquad (21)$$

$$\Phi_\xi = \frac{\sigma_0}{E_0} \sum_{n=0}^{\infty} \phi_\xi^{(n)} \cos n\theta$$

$$\Phi_\theta = \frac{\sigma_0}{E_0} \sum_{n=1}^{\infty} \phi_\theta^{(n)} \sin n\theta \tag{22}$$

$$\epsilon_\xi = \frac{\sigma_0}{E_0} \sum_{n=0}^{\infty} e_\xi^{(n)} \cos n\theta$$

$$\epsilon_\theta = \frac{\sigma_0}{E_0} \sum_{n=0}^{\infty} e_\theta^{(n)} \cos n\theta$$

$$\epsilon_{\xi\theta} = \frac{\sigma_0}{E_0} \sum_{n=1}^{\infty} e_{\xi\theta}^{(n)} \sin n\theta \tag{23}$$

$$\kappa_\xi = \frac{\sigma_0}{aE_0} \sum_{n=0}^{\infty} k_\xi^{(n)} \cos n\theta$$

$$\kappa_\theta = \frac{\sigma_0}{aE_0} \sum_{n=0}^{\infty} k_\theta^{(n)} \cos n\theta$$

$$\kappa_{\xi\theta} = \frac{\sigma_0}{aE_0} \sum_{n=1}^{\infty} k_{\xi\theta}^{(n)} \sin n\theta \tag{24}$$

These Fourier expansions are consistent with loadings of the forms

$$q = \frac{\sigma_0 h_0}{a} \sum_{n=0}^{\infty} p^{(n)}(\xi) \cos n\theta$$

$$q_\xi = \frac{\sigma_0 h_0}{a} \sum_{n=0}^{\infty} p_\xi^{(n)}(\xi) \cos n\theta$$

$$q_\theta = \frac{\sigma_0 h_0}{a} \sum_{n=1}^{\infty} p_\theta^{(n)}(\xi) \sin n\theta \tag{25}$$

and a temperature distribution

$$T = \sum_{n=o}^{\infty} T^{(n)}\,(\xi,\zeta)\cos n\theta \tag{26}$$

The various field equations now can be decoupled into separate sets for each Fourier index n; for convenience, the superscript (n) on Fourier coefficients will be omitted in the equations that follow. The equilibrium equations (Equation 10) lead to

$$\begin{aligned}
&t_\xi' + \gamma(t_\xi - t_\theta) + (n/\rho)t_{\xi\theta} + \lambda^2 \Big| \omega_\xi m_\xi' + \\
&\quad \gamma\omega_\xi(m_\xi - m_\theta) + (n/2\rho)\,(3\omega_\xi - \omega_\theta)m_{\xi\theta}\Big| + p_\xi = 0 \\
&t_{\xi\theta}' + 2\gamma t_{\xi\theta} - (n/\rho)t_\theta + \lambda^2 \Big| -(n/\rho)\omega_\theta m_\theta + \\
&\frac{1}{2}(3\omega_\theta - \omega_\xi)m_{\xi\theta}' + \frac{1}{2}\Big|\gamma(3\omega_\theta + \omega_\xi) - \omega_\xi'\Big| m_{\xi\theta}\Big| + p_\theta = 0 \\
&-\omega_\xi t_\xi - \omega_\theta t_\theta + \lambda^2 \Big| m_\xi'' + 2\gamma m_\xi' - \omega_\xi\omega_\theta m_\xi + \\
&\qquad \Big|\omega_\xi\omega_\theta - (n^2/\rho^2)\Big| m_\theta - \gamma m_\theta' + (2n/\rho)m_{\xi\theta}' + \\
&\qquad\qquad (2\gamma n/\rho)m_{\xi\theta}\Big| + p = 0
\end{aligned} \tag{27}$$

where $\lambda = h_0/a$, and use has been made of the geometrical identities Equations 6 and 7). The relations (Equations 11 through 13) give

$$\phi_\xi = -w' + \omega_\xi u_\xi \tag{28a}$$

$$\phi_\theta = (n/\rho)w + \omega_\theta u_\theta \tag{28b}$$

$$e_\xi = u_\xi' + \omega_\xi w$$

$$e_\theta = (n/\rho)u_\theta + \gamma u_\xi + \omega_\theta w$$

$$e_{\xi\theta} = \frac{1}{2}\Big| u_\theta' - \gamma u_\theta - (n/\rho)u_\xi \Big| \tag{29}$$

$$k_\xi = \phi_\xi' \qquad k_\theta = (n/\rho)\,\phi_\theta + \gamma\phi_\xi$$

$$k_{\xi\theta} = \frac{1}{2}\Big\{ -(n/\rho)\phi_\xi + \phi_\theta' - \gamma\phi_\theta + \frac{1}{2}(\omega_\theta - \omega_\xi)\Big[(nu_\xi/\rho) + u_\theta' + \gamma\, u_\theta\Big]\Big\} \tag{30}$$

and finally, the constitutive relations (Equations 17 and 18), inverted to give forces and moments in terms of strains and bending distortions, lead to

$$t_\xi + b(e_\xi + \nu\, e_\theta) - t_T^{(n)} \qquad t_\theta = b(e_\theta + \nu\, e_\xi) - t_T^{(n)} \tag{31}$$

$$t_{\xi\theta} = b(1 - \nu)e_{\xi\theta}$$

and

$$m_\xi = d(k_\xi + \nu k_\theta) - m_T^{(n)} \tag{32a}$$

$$m_\theta = d(k_\theta + \nu k_\xi) - m_T^{(n)} \tag{32b}$$

$$m_{\xi\theta} = d(1 - \nu)k_{\xi\theta} \tag{32c}$$

where

$$b = \frac{\int E d\zeta}{E_o h_o (1 - \nu^2)} \tag{33}$$

$$d = \frac{\int \zeta^2 E d\zeta}{E_o h_o^3 (1 - \nu^2)} \tag{34}$$

$$t_T^{(n)} = \frac{\int E\alpha T^{(n)} d\zeta}{\sigma_o h_o (1 - \nu)} \tag{35}$$

$$m_T^{(n)} = \frac{a\int \zeta E\alpha T^{(n)} d\zeta}{\sigma_o h_o^3 (1 - \nu)} \tag{36}$$

(Again, the superscript (n) on $t_T^{(n)}$ and $m_T^{(n)}$ will be omitted henceforth.)

For each n, the set of field equations for the 17 Fourier coefficients t_ξ, t_θ, $t_{\xi\theta}$, m_ξ, m_θ, $m_{\xi\theta}$, u_ξ, u_θ, w, ϕ_ξ, ϕ_θ, e_ξ, e_θ, $\epsilon_{\xi\theta}$, k_ξ, k_θ, $k_{\xi\theta}$ now is given by the 17 equations (Equations 27 through 32):

It may be remarked at this point that the Fourier expansions (Equations 25 and 26), which are symmetrical about $\theta = 0$ for q, q_ξ, and T and antisymmetrical for q_θ are not the most general that could exist. For full generality, these expansions should be augmented by the additional series

$$\bar{q} = \frac{\sigma_0 h_0}{a} \sum_{n=1}^{\infty} \bar{p}^{(n)}(\xi) \sin n\theta$$

$$\bar{q}_\xi = \frac{\sigma_0 h_0}{a} \sum_{n=1}^{\infty} \bar{p}_\xi^{(n)}(\xi) \sin n\theta$$

$$\bar{q}_\theta = \frac{\sigma_0 h_0}{a} \sum_{n=0}^{\infty} \bar{p}_\theta^{(n)}(\xi) \cos n\theta$$

$$\bar{T} = \sum_{n=1}^{\infty} \bar{T}^{(n)}(\xi,\zeta) \sin n\theta \tag{25a}$$

In this case, the form of the shell field equations can be obtained by setting the Fourier harmonics (n) to negative values in Equations 27 through 32. These effects have been neglected in this program but can be included with minor modifications of the program.

1.8 REDUCTION TO FOUR SECOND-ORDER DIFFERENTIAL EQUATIONS

The set of field equations obtained constitutes an eighth-order system that can be reduced, in a conventional fashion, to three equations in u_ξ, u_θ, and w. But a more attractive procedure is to derive four differential equations, each of second order, in the variables u_ξ, u_θ, w, and m_ξ. In so doing, it is necessary to eliminate m_θ by means of the relation

$$m_\theta = \nu m_\xi + d(1-\nu^2)k_\theta - (1-\nu)m_T \tag{37}$$

in order to prevent the ultimate appearance of derivatives of order higher than two. Then, substituting Equations 37, 32c, and 31 into Equation 27 and using Equations 28 through 30 to eliminate the membrane strain and bending distortion gives three of the desired equations; the fourth equation is given by Equation 32a, again with k_ξ and k_θ expressed in terms of the displacements. The resultant set then can be written as

$$
\begin{aligned}
&a_1 u_\xi'' + a_2 u_\xi' + a_3 u_\xi + a_4 u_\theta' + a_5 u_\theta + a_6 w_6' + \\
&\qquad a_7 w + a_8 m_\xi' + a_9 m_\xi = C_1 \\
&a_{10} u_\xi' + a_{11} u_\xi + a_{12} u_\theta'' + a_{13} u_\theta' + a_{14} u_\theta + \\
&\qquad a_{15} w'' + a_{16} w' + a_{17} w + a_{18} m_\xi = C_2 \\
&a_{19} u_\xi' + a_{20} u_\xi + a_{21} u_\theta'' + a_{22} u_\theta' + a_{23} u_\theta + \\
&a_{24} w'' + a_{25} w' + a_{26} w + a_{27} m_\xi'' + a_{28} m_\xi' + \\
&\qquad a_{29} m_\xi = C_3 \\
&a_{30} u_\xi' + a_{31} u_\xi + a_{32} u_\theta + a_{33} w'' + a_{34} w' + \\
&\qquad a_{35} w + a_{36} m_\xi = C_4
\end{aligned}
\tag{38}
$$

where the a's and c's are given in Appendix A. These equations can be written in the matrix form

$$
Ez'' + Fz' + Gz = e \tag{39}
$$

where

$$
z = \begin{bmatrix} u_\xi \\ u_\theta \\ w \\ m_\xi \end{bmatrix} \tag{40}
$$

and

$$E = \begin{bmatrix} a_1 & 0 & 0 & 0 \\ 0 & a_{12} & a_{15} & 0 \\ 0 & a_{21} & a_{24} & a_{27} \\ 0 & 0 & a_{33} & 0 \end{bmatrix} \qquad F = \begin{bmatrix} a_2 & a_4 & a_6 & a_8 \\ a_{10} & a_{13} & a_{16} & 0 \\ a_{19} & a_{22} & a_{25} & a_{28} \\ a_{30} & 0 & a_{34} & 0 \end{bmatrix}$$

$$G = \begin{bmatrix} a_3 & a_5 & a_7 & a_9 \\ a_{11} & a_{14} & a_{17} & a_{18} \\ a_{20} & a_{23} & a_{26} & a_{29} \\ a_{31} & a_{32} & a_{35} & a_{36} \end{bmatrix} \qquad e = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} \tag{41}$$

1.9 BOUNDARY CONDITIONS

In the Sanders theory, the expressions for virtual work per unit length at the boundaries $s = 0, \bar{s}$ are

$$\mp \left(N_\xi U_\xi + \hat{N}_{\xi\theta} U_\theta + \hat{Q}_\xi W + M_\xi \Phi_\xi\right) \tag{42}$$

where

$$\hat{N}_{\xi\theta} = \bar{N}_{\xi\theta} + \left[(3/2R_\theta) - (1/2R_\xi)\right] \bar{M}_{\xi\theta} \tag{43}$$

and

$$\hat{Q}_\xi = (1/a\rho) \left[(\partial/\partial\xi)(\rho M_\xi) + 2(\partial \bar{M}_{\xi\theta}/\partial\theta) - \rho' M_\theta\right] \tag{44}$$

are "effective" membrane and transverse shears, respectively, per unit length. (See Figure 1-4.) This form of the virtual work indicates the kinds of boundary conditions that can be imposed; thus, either N_ξ or U_ξ may be prescribed, either $\hat{N}_{\xi\theta}$ or U_θ may be prescribed, and so on; or, more generally, N_ξ and U_ξ may be related through an elastic constraint against meridional displacement; and analogous constraints can link $\hat{N}_{\xi\theta}$ and U_θ, $\hat{Q}_\xi$ and W, and M_ξ and Φ_ξ. Letting

$$\hat{N}_{\xi\theta} = \sigma_0 h_0 \sum_{n=1}^{\infty} \hat{t}_{\xi\theta}^{(n)} \sin n\theta$$

$$\hat{Q}_{\xi} = \sigma_0 h_0 \sum_{n=0}^{\infty} \hat{f}_{\xi}^{(n)} \cos n\theta$$

gives (dropping superscripts)

$$\begin{aligned} \hat{t}_{\xi\theta} &= t_{\xi\theta} + (\lambda^2/2)(3\omega_\theta - \omega_\xi)m_{\xi\theta} \\ \hat{f}_{\xi} &= \lambda^2 \left| m_\xi' + \gamma(m_\xi - m_\theta) + (2n/\rho)m_{\xi\theta} \right| \end{aligned} \tag{46}$$

Then the boundary conditions just discussed always can be written (for the nth Fourier components) as

$$\Omega y + \Lambda z = \ell \tag{47}$$

where

$$y = \begin{bmatrix} t_\xi \\ \hat{t}_{\xi\theta} \\ \hat{f}_\xi \\ \phi_\xi \end{bmatrix} \tag{48}$$

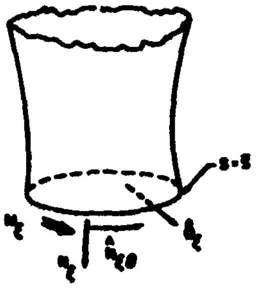


Figure 1-4. Effective Boundary Forces and Moment

and where Ω and Λ are appropriate diagonal matrices, and ℓ is a given column matrix. (For example, if u_ξ is given, the first diagonal element of Ω is zero, that of Λ is unity, and the first element of ℓ is the prescribed value of u_ξ; if there is an elastic constraint on u_ξ, then the first diagonal element of Ω is unity, that of Λ is the appropriate constraint coefficient, and the first element of ℓ vanishes.) But now it is desirable to express the boundary conditions entirely in terms of z; from Equations 28 through 32 and 37, it follows that

$$\begin{aligned} t_\xi &= b_1 u_\xi' + b_2 u_\xi + b_3 u_\theta + b_4 w - t_T \\ \hat{t}_{\xi\theta} &= b_5 u_\xi + b_6 u_\theta' + b_7 u_\theta + b_8 w' + b_9 w \\ \hat{f}_\xi &= b_{10} u_\xi + b_{11} u_\theta' + b_{12} u_\theta + b_{13} w' + b_{14} w + b_{15} m_\xi' \\ &\quad + b_{16} m_\xi + \lambda^2 \gamma (1 - \nu) m_T \end{aligned} \tag{49}$$

where the b's are given in Appendix A. These equations, together with Equation 28a, give

$$y = Hz' + Jz + f \tag{50}$$

where

$$H = \begin{bmatrix} b_1 & 0 & 0 & 0 \\ 0 & b_6 & b_8 & 0 \\ 0 & b_{11} & b_{13} & b_{15} \\ 0 & 0 & -1 & 0 \end{bmatrix} \qquad f = \begin{bmatrix} -t_T \\ 0 \\ \lambda^2 \gamma (1 - \nu) m_T \\ 0 \end{bmatrix}$$

$$J = \begin{bmatrix} b_2 & b_3 & b_4 & 0 \\ b_5 & b_7 & b_9 & 0 \\ b_{10} & b_{12} & b_{14} & b_{16} \\ \omega_\xi & 0 & 0 & 0 \end{bmatrix} \tag{51}$$

Hence, the boundary conditions (Equation 47) can be written as

$$\Omega H z' + (\Lambda + \Omega J) z = \ell - \Omega f \tag{52}$$

1.10 SINGULAR POINTS (APEX CONDITION)

If the shell has a pole (i.e., $r = 0$), coefficients in the governing differential equations become singular. An improved procedure for handling such conditions has been outlined in References 8 and 9 and is used in the analysis. The boundary conditions at the apex of a closed shell of revolution are described as follows for each Fourier component (n)

$$\begin{array}{ll}
u_\xi = u_\theta = w' = w_\xi{}' = 0 & \text{for } n = 0 \\
u_\xi{}' = u_\xi + u_\theta = w = m_\xi = 0 & \text{for } n = 1 \\
u_\xi = u_\theta = w = w' = 0 & \text{for } n = 2 \\
u_\xi = u_\theta = w = m_\xi = 0 & \text{for } n \geq 3
\end{array}$$

These special conditions can be cast in a matrix form identical to Equation 52. For this case, the matrix $\Lambda + \Omega J$ is not of a diagonal form.

1.11 DISCONTINUITY CONDITIONS

The differential equations (39) are not valid at points in the shell in which discontinuities in geometry (and hence in the coefficients) occur; furthermore, z itself is ambiguous at a discontinuity in the inclination of the reference surface, where the directions of u_ξ and w change abruptly. Accordingly, special transition equations must be derived which relate z and its derivative on either side of a discontinuity.

In Reference 1, the special case in which reference surfaces coincide across a discontinuity was considered. (See Figure 1-5.) A more general condition, which was treated in Reference 2, occurs when reference surfaces do not coincide at discontinuities. This type of condition is considered for this program and will be referred to as eccentric discontinuities. The effects of external line load end moments applied at the discontinuity are included in the analysis (Figure 1-5). A typical eccentric discontinuity model is shown in Figure 1-6. Roman numeral superscripts refer to shell regions; thus, for the example considered, II denotes values beyond and I values ahead of a discontinuity. The conconditions of geometrical compatibility are (Figures 1-5 and 1-6)

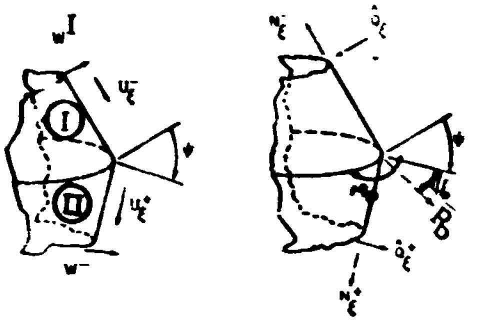


Figure 1-5. Discontinuity Conditions

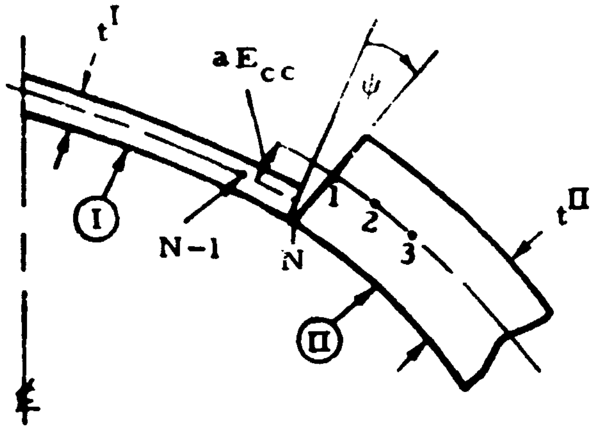


Figure 1-6. Eccentric Discontinuity Model

$$
\begin{aligned}
u_\xi^{II} &= \left[u_\xi^{I} + E_{cc}\phi_\xi^{I} \right] \cos\psi - w^I \sin\psi \\
u_\theta^{II} &= u_\theta^{I} + E_{cc}\phi_\theta^{I} \\
w^{II} &= \left[u_\xi^{I} + E_{cc}\phi_\xi^{I} \right] \sin\psi + w^I \cos\psi \\
\phi_\xi^{II} &= \phi_\xi^{I}
\end{aligned}
\tag{53}
$$

where E_{cc} is the dimensionless eccentricity of the participating reference surfaces measured along the radius of curvature behind the discontinuity point. It can be noted in Figure 1-6 that a positive value of E_{cc} corresponds to an abrupt increase in the radius of a parallel circle as one proceeds in the direction of increasing ξ. Equilibrium requires that

$$
\begin{aligned}
t_\xi^{II} &= t_\xi^{I} \cos\psi - \hat{f}_\xi^{I} \sin\psi + P_D \sin\psi_o \\
\hat{t}_{\xi\theta}^{II} &= \hat{t}_{\xi\theta}^{I} \\
\hat{f}_\xi^{II} &= t_\xi^{I} \sin\psi + \hat{f}_\xi^{I} \cos\psi - P_D \cos\psi_o \\
m_\xi^{II} &= m_\xi^{I} - \frac{E_{cc}}{\lambda^2} t_\xi^{I} - M_D
\end{aligned}
\tag{54}
$$

where P_D and M_D are Fourier coefficients of series expansions for externally applied line loads and moments; i.e.,

$$\overline{P}_D = \frac{\sigma_0 h_0}{a} \sum_{n=0}^{\infty} P_D \cos n\theta$$

$$\overline{M}_D = \frac{\sigma_0 h_0^{3}}{a} \sum_{n=0}^{\infty} M_D \cos n\theta$$

The information in Equations 53 and 54 is reproduced in the equations

$$y^{II} = \Psi y^{I} + \Phi_o \; P_D \tag{55}$$

$$z^{II} = \Lambda z^{I} + \Join y^{I} + \Upsilon M_D \tag{56}$$

where

$$\Psi = \begin{bmatrix} \cos\psi & 0 & -\sin\psi & 0 \\ 0 & 1 & 0 & 0 \\ \sin\psi & 0 & \cos\psi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{57}$$

$$\Lambda = E_{cc} \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & (\omega_\theta)_j I & n/\rho_j I & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} + \overline{\Psi} \tag{58}$$

$$\Join = E_{cc} \begin{bmatrix} 0 & 0 & 0 & \cos\psi \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sin\psi \\ -1/\lambda^{2} & 0 & 0 & 0 \end{bmatrix} \tag{59}$$

$$\Phi_o = \begin{bmatrix} \sin\psi_o \\ 0 \\ -\cos\psi_o \\ 0 \end{bmatrix} \qquad (60)$$

$$\eta = \begin{bmatrix} 0 \\ 0 \\ 0 \\ -1 \end{bmatrix} \qquad (61)$$

Combining Equations 55, 56, and 50 then provides the equations relating $(z')^{II}$, $(z')^{I}$, and z^I:

$$H^{II}(z^{II})' + \left[J^{II}\Psi - \Psi J^I\right] z^I - \Psi H^I (z^I)' = \Phi_o P_D + \Psi f^I - f^{II} \qquad (62a)$$

$$z^{II} = \Lambda z^I + \Omega \left[H^I z^I + \Omega J^I z^I + \Omega f^I + \eta M_D \right] \qquad (62b)$$

where the Roman numerals I and II mean that the matrices H, J, and f are to be calculated from Equation 51 on the basis of shell properties just behind and ahead of the discontinuity, respectively. The equlibrium equations (39), the boundary conditions (52), and the discontinuity conditions (62) will now be cast into a unified set of appropriate finite-difference equations suitable for numerical analysis.

1.12 FINITE DIFFERENCE FORMULATION

A finite difference technique will be used in the solution of the shell equations. In treating complicated shell configurations, it will at times be necessary and convenient for analysis purposes to divide the mathematical model of the shell in combinations of smaller region. The dividing line between regions is usually selected at discontinuity regions. (See Section 2.5.) In the finite difference formulation, the path region will be subdivided into (N^P-1) equal increments of length Δ^P. N^P corresponds to the number of station or pivotal points considered for the region. The pivotal points are identified along the meridian by the integer index i, starting from i = 1 at $\xi = 0$ (station 1) and proceeding to N-th station (i = N) occurring at the endpoint of the region (see Figure 1-7).

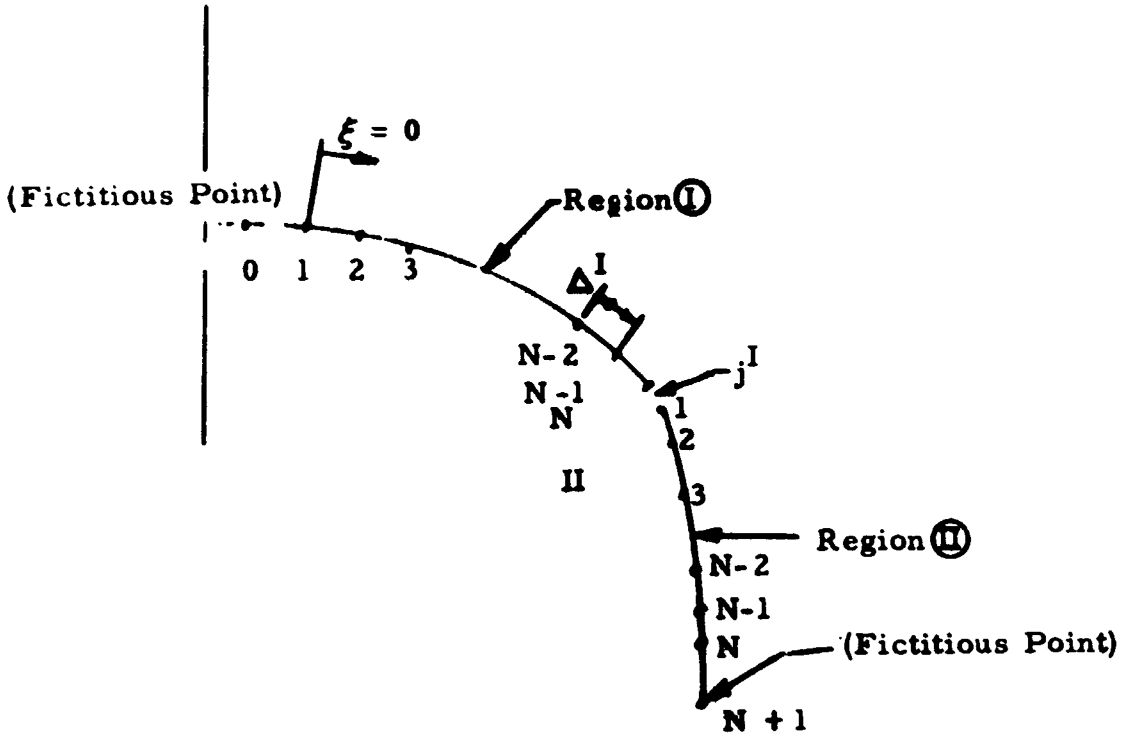


Figure 1-7. **Meridional Grid Points**

The regions are designated by Roman numeral superscripts I, II, etc., and discontinuity stations by $i = J^P$. For the discontinuity junction illustrated in Figure 1-8, the discontinuity j^I would correspond to station $i = N$ of region I, j^{II} station $i = 1$ of region II, etc. The increment Δ^P can be varied from region to region. Thus, it is possible to introduce fictitious discontinuities wherever a change in increment size is considered desirable.

The differential equations (39), boundary conditions (52) (excepting the closed apex condition), and discontinuity conditions (62) are written in finite difference form at all stations on the basis of the usual central difference formulas

$$z_i'' = (z_{i+1} - 2z_i + z_{i-1})/\Delta^2$$

$$z_i' = (z_{i+1} - z_{i-1})/2\Delta \qquad (63)$$

where the Δ must, of course, be the one corresponding to the region associated with the station i.

Applying the above expressions at the endpoints of a region ($i = 1, N$) results in fictitious points occurring outside the range of the region (i.e., $i = 0, N + 1$). Figure 1-8 illustrates the mathematical model used at a discontinuity point with fictitious points j^{II-1} and j^{I+1} resulting from application of difference expressions

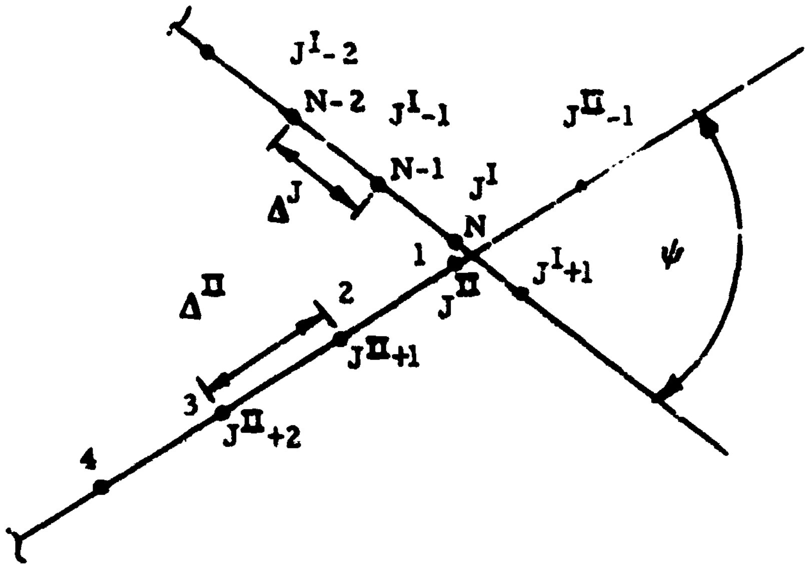


Figure 1-8. Finite Difference Stations in Discontinuity Region

The fictitious points can be mathematically eliminated by applying both boundary (or discontinuity) and equilibrium conditions at the endpoints. The details of this type of operation are described in Reference 2. In the original analysis of Reference 1, a somewhat different approach was utilized in that equilibrium was not satisfied at endpoints. The improved procedure of Reference 2 permits a more accurate representation of shell behavior at endpoints.

In case of a pole condition ($r = 0$), the singularity does not permit writing both equilibrium and compatibility; as a result, the procedure must be modified for this case. The approach used for this special case is to express derivatives at endpoints in terms of modified forward (backward) differences. The boundary condition for a pole condition will be written at $i = 0$ and $i = N$ with the help of

$$z'_1 = (-3\,z_1 + 4\,z_2 - z_3)/2\Delta$$

$$z'_N = (3\,z_N - 4\,z_{N-1} + z_{N-2})/2\Delta \qquad (64)$$

The order of approximation of these expressions is the same as the usual central difference expressions and is usually more accurate than simple forward or backward difference expressions used in Reference 1.

The convention will now be adopted that, at the discontinuity (say $P = 1$), whenever z_j is written without a qualifying superscript, it means z_j^I; then, whenever z_j^{II} appears, it will be replaced by utilizing relationship according to Equation 58b. Similar operations would occur for subsequent discontinuities. The results of writing the various difference equations just described can be stated compactly (excepting for pole conditions) as the following set of algebraic equations for z_i $(i = 1, 2, 3, \ldots N)$:

$$A_1 z_2 + B_1 z_1 = g_1 (i = 1)$$

$$A_i z_{i+1} + B_i z_i + C_i z_{i-1} = g_i \quad (i = 2, 3, \ldots N - 1)$$

$$B_N z_N + C_N z_{N-1} = g_N (i = N) \tag{65}$$

Here, at $i = 2, 3, \ldots N - 1$ the internal points of the region we have

$$A_i = (2E_i/\Delta) + F_i$$

$$B_i = -(4E_i/\Delta) + 2\Delta G_i$$

$$C_i = (2E_i/\Delta) - F_i$$

$$g_i = 2\Delta e_i \tag{66}$$

where the appropriate value for Δ is used.

At $i = 1$, we have been using the procedure outlined above and described in Reference 2 following

$$A_1 = \frac{\Omega_1 H_1}{2\Delta_1} + \frac{\Omega_1 H_1}{2\Delta_1} \overline{C}_1^{-1} \overline{A}_1$$

$$B_1 = \Lambda_1 + \Omega_1 J_1 + \frac{\Omega_1 H_1}{2\Delta_1} \overline{C}_1^{-1} \overline{B}_1$$

$$g_1 = \ell_1 - \Omega_1 f_1 + \frac{\Omega_1 H_1}{2\Delta_1} \overline{C}_1^{-1} 2\Delta_1 e_1 \tag{67}$$

and i = N

$$B_N = \Lambda_N + \Omega_N J_N - \Omega_N H_N \bar{A}_N^{-1} \bar{B}_N$$

$$C_N = - \frac{\Omega_N H_N}{2\Delta_{N-1}} - \frac{\Omega_N H_N}{2\Delta_{N-1}} \bar{A}_N^{-1} \bar{C}_N$$

$$g_N = \ell_N - \Omega_N f_N - \frac{\Omega_N H_N}{2\Delta_{N-1}} \bar{A}_N^{-1} 2\Delta_{N-1} e_N \tag{68}$$

where the matrices $\bar{A}_1, \bar{B}_1, \bar{C}_1$ and $\bar{A}_N, \bar{B}_N, \bar{C}_N$ are of the form of Equation 66 evaluated at i - 1 and N, respectively.

At discontinuity locations j^P, considerably more complicated expressions for the matrices are obtained than are reported in Reference 1, which arises due to the improved numerical model and the fact that eccentric discontinuities are considered. The details of obtaining these expressions are reported in Reference 2. As a result, the following form of the matrices of discontinuity location is obtained:

$$A_j = \frac{H^{II}}{2\Delta^{II}} + \left(\frac{H^{II}}{2\Delta^{II}}\right) \cdot (C^{II})^{-1} \cdot A^{II}$$

$$B_j = \left(\frac{H^{II}}{2\Delta^{II}}\right) \cdot (C^{II})^{-1} B^{II} \cdot \left[\mathbb{1} - \left(\frac{\bowtie H^I}{2\Delta^I}\right) (A^I)^{-1} \cdot B^I + \bowtie J^I \right] + \left|Y\right|$$
$$- \left|X\right| \cdot (A^I)^{-1} \cdot B^I$$

$$C_j = - \left(\frac{H^{II}}{2\Delta^{II}}\right) (C^{II})^{-1} \cdot B^{II} \left(\frac{\bowtie H^I}{2\Delta^I} \cdot + \frac{\bowtie H^I}{2\Delta^I}\right) \cdot (A^I)^{-1} \cdot C^I \Big]$$
$$- \left|X\right| \cdot (A^I)^{-1} C^I - \left|X\right|$$

$$g_j = \left(\frac{H^{II}}{2\Delta^{II}}\right) \cdot (C^{II})^{-1} \cdot \left[g^{II} - B^{II} \cdot \left(\frac{\bowtie H^I}{2\Delta^I}\right) \cdot (A^I)^{-1} \cdot g^I - B^{II} \bowtie f^I \right]$$
$$- \left|X\right| \cdot (A^I)^{-1} g^I - \left|L\right| \tag{69}$$

where

$$\left| X \right| = (J^{II} \divideontimes - \Psi) \cdot \left(\frac{H^{I}}{2\Delta^{I}} \right)$$

$$\left| Y \right| = J^{II} \left(\Uparrow + \divideontimes J^{I} \right) - \Psi \cdot J^{I}$$

$$\left| L \right| = (J^{II} \divideontimes - \Psi) f^{I} + f^{II} \qquad (70)$$

The A, B, C, and g matrices in Equation 69 are given for either points j^{I} or j^{II} by Equation 66 with the appropriate superscript attached to E, F, G and Δ. At station just past a discontinuity $(j^{II} + 1)$ the matrices must be modified as follows:

$$C^{*}_{j+1} = C^{II}_{j+1} \left\{ \left[\Uparrow + \divideontimes J^{I} - \divideontimes \frac{H^{I}}{2\Delta^{I}} \cdot (A^{I})^{-1} \cdot B^{I} \right] + \frac{\divideontimes H^{I}}{2\Delta^{I}} \left[I + A^{I^{-1}} C^{I} \right] P^{I}_{j-1} \right\}$$

$$g^{*}_{j+1} = g^{II}_{j+1} - C^{II}_{j+1} \divideontimes f^{I} - C^{II}_{j+1} \left[\frac{\divideontimes H^{I}}{2\Delta^{I}} \cdot (A^{I})^{-1} g^{I} \right] + C^{II}_{j+1} \left\{ \frac{\divideontimes H^{I}}{2\Delta^{I}} \left[I + (A^{I})^{-1} \cdot C^{I} \right] \right\} X^{I}_{j-1} \qquad (71)$$

1.13 MATRIX SOLUTION OF DIFFERENCE EQUATIONS

The set of matrix equations (65) will be solved by essentially the same formal procedure that is used in Reference 1 for the analogous equation for the case of axisymmetric loading of shells of revolution; this procedure is actually equivalent to solution by the method of Gaussian elimination used in Reference 1 for the same axisymmetric loading problem. In its most primitive form, the Gaussian elimination technique would proceed as follows: the first of Equations 65 would be solved for z_1 in terms of z_2; this result would be substituted into the next equation, and z_2 would be found in terms of z_3 and so on; finally, the very last equation, together with the result for z_{N-1} in terms of z_N would determine z_N and then all of the z's would be calculated in reverse order. A minor modification of this method is desirable, however (and sometimes essential), in the treatment of Equation 65 for the matrix B_0 sometimes may be singular.* Accordingly, the solution is started by the simultaneous solution for z_0 and z_1, in terms of z_2 and then proceeds as just described. From

$$A_1 z_2 + B_1 z_1 = g_1$$

$$B_2 z_2 + C_2 z_1 = g_2 - A_2 z_3$$

it follows that

$$z_2 = - \left| B_1 C_2^{-1} B_2 - A_1 \right|^{-1} \left| B_1 C_2^{-1} A_2 z_3 - B_1 C_2^{-1} g_2 + g_1 \right| \qquad (72)$$

Now write the general result for z_i in terms of z_{i+1} as

$$z_i = - P_i z_{i+1} + x_i \quad (i = 1, 2, \ldots N - 1) \qquad (73)$$

Then, the substitution of $z_{i-1} = - P_{i-1} z_i + x_{i-1}$ into the general equation (65) provides the results

$$P_i = \left| B_i - C_i P_{i-1} \right|^{-1} A_i$$

$$x_i = \left| B_i - C_i P_{i-1} \right|^{-1} \left| g_i - C_i x_{i-1} \right| \quad (i = 2, 3, \ldots N - 1) \qquad (74)$$

---

*This occurs, for example, in the case of a clamped edge, with $u_\xi = u_\theta = w = \phi_\xi = 0$; then

giving

$$\mathcal{L}_0 = 0$$

$$\Omega_0 = \begin{bmatrix} 0 & & & \\ & 0 & & \\ & & 0 & \\ & & & 1 \end{bmatrix} \quad A_0 = \begin{bmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & 0 \end{bmatrix} \quad B_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \omega_\xi & 0 & 1/\Delta & 0 \end{bmatrix}$$

which is singular.

The recurrence relations (Equation 74), with the initial from (Equation 72),

$$P_2 = \left| B_1 C_2^{-1} B_2 - A_1 \right|^{-1} B_1 C_2^{-1} A_2$$

$$x_2 = \left| B_1 C_2^{-1} B_2 - A_1 \right|^{-1} \quad B_1 C_2^{-1} g_2 - g_1 \tag{75}$$

then provide all the P's and x's up to P_{N-1} and x_{N-1}. Substitution of $z_{N-1} = - P_{N-1} z_N + x_{N-1}$ into the last of Equation (66) then gives

$$z_N = \left| B_N - C_N P_{N-1} \right|^{-1} \left| g_N - C_N x_{N-1} \right| \tag{76}$$

and then z_{N-1}, z_{N-2}, . . . z_1 can be found from Equation 73. Finally, z_0 is given by

$$z_1 = C_2^{-1} \left| g_2 - A_2 z_1 - B_2 z_3 \right| \tag{77}$$

Thus, the only matrix inversions involved in the solution for all the z's are of 4 x 4 matrices, and the process is very well suited for rapid machine computation. The z_j obtained at a discontinuity station is, of course, really z_j^I. The value of z_j^{II} at this point can be evaluated from Equation 62b. For a singular or pole condition, a slight modification in the elimination procedure is involved to accommodate for finite difference form (Equation 64) applied at an endpoint. The details of this procedure are described in Reference 2.

1.14 CALCULATION OF STRESSES

Once the z's have been calculated, the stresses at any point in the shell can be found. The stresses in the present solution are obtained from the expansions

$$\sigma_\xi = \sum_{n=0}^{\infty} \sigma_\xi^{(n)} \cos n\theta$$

$$\sigma_\theta = \sum_{n=0}^{\infty} \sigma_\theta^{(n)} \cos n\theta$$

$$\sigma_{\xi\theta} = \sum_{n=1}^{\infty} \sigma_{\xi\theta}^{(n)} \sin n\theta \tag{78}$$

Inverting the constitutive relations (Equation 15) and using Equations 23, 24, and 26 gives

$$\sigma_\xi{}^{(n)} = \frac{E\sigma_0}{E_0(1-\nu^2)}\left[e_\xi{}^{(n)} + \nu e_\theta{}^{(n)} + \frac{\zeta}{a}(k_\xi{}^{(n)} + \nu k_\theta{}^{(n)})\right] - \frac{E\alpha T^{(n)}}{1-\nu}$$

$$\sigma_\theta{}^{(n)} = \frac{E\sigma_0}{E_0(1-\nu^2)}\left[e_\theta{}^{(n)} + \nu e_\xi{}^{(n)} + \frac{\zeta}{a}(k_\theta{}^{(n)} + \nu k_\theta{}^{(n)}\right] - \frac{E\alpha T^{(n)}}{1-\nu}$$

$$\sigma_{\xi\theta}{}^{(n)} = \frac{E\sigma_0}{E_0(1+\nu)}\left[e_{\xi\theta}{}^{(n)} + \frac{\zeta}{a}k_{\xi\theta}{}^{(n)}\right] \tag{79}$$

Note that E, α , and $T^{(n)}$ all may depend on ζ , the distance from the reference surface.

Using Equations 32a, 32b, and 37 (and, again, casually dropping superscripts n) gives

$$k_\xi + \nu k_\theta = \frac{m_\xi + m_T}{d}$$

$$k_\theta + \nu k_\xi = \frac{m_\theta + m_T}{d} = \frac{\nu(m_\xi + m_T)}{d} + (1-\nu^2)k_\theta$$

which, when used in Equation 79, together with the strain-rotation-displacement equations (28 through 30), leads to

$$\begin{bmatrix} \sigma_\xi{}^{(n)} \\ \sigma_\theta{}^{(n)} \\ \sigma_{\xi\theta}{}^{(n)} \end{bmatrix} = Kz' + Lz + \sigma_T \tag{80}$$

$$K = \frac{E\sigma_0}{E_0(1-\nu^2)}\begin{bmatrix} 1 & 0 & 0 & 0 \\ \nu & 0 & -\frac{\zeta\gamma(1-\nu^2)}{a} & 0 \\ 0 & \frac{1-\nu}{2}\cdot\left[1 + \frac{\zeta}{2a}(3\omega_\theta - \omega_\xi)\right] & \frac{\zeta}{a}(1-\nu)\frac{n}{\rho} & 0 \end{bmatrix} \tag{81}$$

$$L \cdot \frac{E_{\sigma_0}}{E_0(1-\nu^2)} \begin{bmatrix} \text{[illegible]} & \text{[illegible]}\, n/\rho & \omega_\xi \text{[illegible]} & /ad \\ \nu\left[1+\frac{(1-\nu^2)\zeta\omega_\xi}{a}\right] & \frac{n}{\rho}\left[1+\frac{(1-\nu^2)\zeta\omega_\theta}{a}\right] & \text{[illegible]} + \frac{(1-\nu^2)\zeta n^2}{a\rho^2} & \text{[illegible]}/ad \\ \left(\frac{1-\nu}{2}\right)\left(\frac{n}{\rho}\right)\left[-1+\frac{(\omega_\theta-3\omega_\xi)\zeta}{2a}\right] & \nu\left(\frac{1-\nu}{2}\right)\left[-1+\frac{(\omega_\xi-3\omega_\theta)\zeta}{2a}\right] & -\frac{(1-\nu)n\gamma\zeta}{a\rho} & 0 \end{bmatrix} \tag{82}$$

$$I' = \begin{bmatrix} \dfrac{E\sigma_0\zeta m_T}{E_0(1-\nu^2)ad} - \dfrac{E\alpha T^{(n)}}{1-\nu} \\ \\ \dfrac{\nu E\sigma_0\zeta m_T}{E_0(1-\nu^2)ad} - \dfrac{E\alpha T^{(n)}}{1-\nu} \\ \\ 0 \end{bmatrix} \tag{83}$$

1.15 REMARK CONCERNING THE REFERENCE SURFACE

A substantial simplification in setting up the numerical analysis for computation may result from the observation that, in the spirit of thin-shell theory, errors of the order of the thickness in the specification of the reference surface can be tolerated in the formulation of the equation of equilibrium. It is recommended accordingly that the key geometric function r(s) be started with respect to a surface chosen simply according to convenience anywhere in the shell wall. In other words, the condition (Equation 1) need not be imposed insofar as calculations of the various geometrical parameters ρ, ω_θ, ω_ξ, and γ are concerned. Of course, if Equation 1 can be satisfied easily in these calculations, there is no harm in doing so; but when, for example, the same shell is to be analyzed for several different temperature conditions with different resultant variations of Young's modulus, it is not recommended that new reference surfaces and new variations of ρ, ω_θ, etc., be calculated for each case. On the other hand, it is essential that the rigorous location of the reference surface enter into Equations 34 and 36 for the nondimensional bending stiffness d and the thermal moment m_T. Similarly, the correct value of ζ as measured from the true reference surface must be used in Equations 80 through 83 for the stresses.

1.16 BRANCHING OF SHELL REGIONS

It has been tacitly assumed that the shell under consideration has no more than two boundaries; a multiple-branch shell such as shown in Figure 1-9a may be analyzed, however, by applying appropriate transition conditions at the branch point.

Define separate families of auxiliary matrices P^I, P^{II}, P^{III}, x^I, x^{II} and x^{III} with the properties

$$\begin{aligned} z_i^I &= - P_i^I z_{i+1}^I + x_i^I \\ z_i^{II} &= - P_i^{II} z_{i+1}^{II} + x_i^{II} \\ z_i^{III} &= - P_i^{III} z_{i+1}^{III} + x_i^{III} \end{aligned} \tag{84}$$

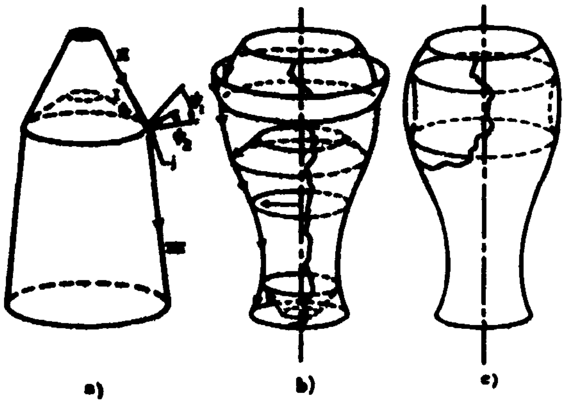


Figure 1-9. Branched Shells

where the superscripts refer to the separate branches shown in Figure 1-9a. It is possible to start the calculations of P^I, x^I and P^{II}, x^{II} at the boundaries of branches I and II and then leap across the juncture j to the calculation of P^{III}, x^{III}. The reverse sweep for the calculation of the z's then would start at the boundary of branch III and, at the juncture j, continue independently along the branches I and II back to their respective boundaries. The details of this procedure are herein given. This method can be extended readily to handle a multiplicity of branches as in Figure 1-9b; it will not, however, be applicable to closed loops (Figure 1-9c), which must be treated separately by traditional cut-and-fit methods of indeterminate structural analysis.

The mathematical model considered for the numerical solution of branched shell problems is shown in Figure 1-10 with the possibility of a concentrated force P_D and M_D applied at the juncture included. The program has been set up to handle 4 shell branches meeting at a common point.

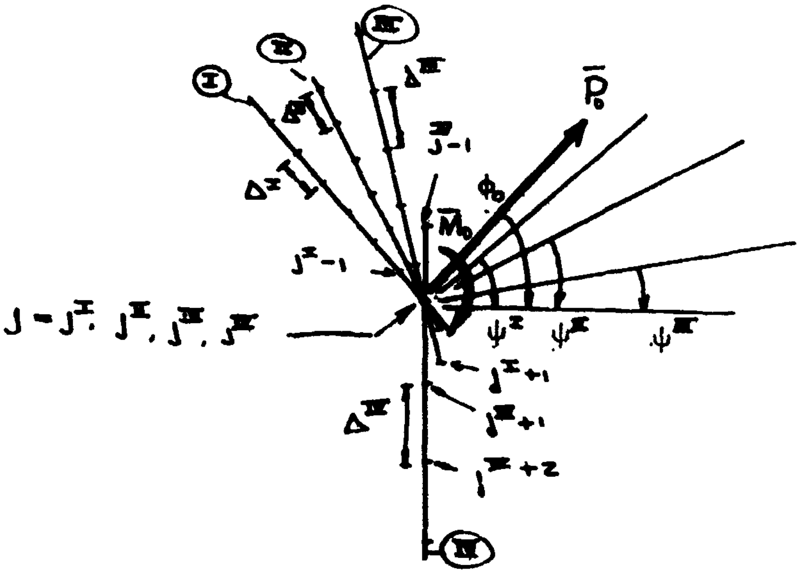


Figure 1-10. Mathematical Model for Branched Shell

By analogy with the previous discussion on discontinuity conditions, we may repeat here for branched shells the compatibility and equilibrium equations in the following manner:

$$\text{Compatibility:}\quad \left.\begin{aligned} u_\xi^{IV} &= u_\xi^{M}\cos\psi^{M} - w^{M}\sin\psi^{M} \\ u_\theta^{IV} &= u_\theta^{M} \\ w^{IV} &= u_\xi^{M}\sin\psi^{M} + w^{M}\cos\psi^{M} \\ \phi_\xi^{IV} &= \phi_\xi^{M} \end{aligned}\right\}\quad (M = I,\ II \text{ or } III) \qquad (85)$$

Equilibrium: $t_{\xi}^{IV} - \sum_{M=I}^{III} t_{\xi}^{M} \cos\psi^{M} + \sum_{M=I}^{III} \hat{f}_{\xi}^{M} \sin\psi^{M} - \overline{P} \sin\Phi_{0} = 0$

$$t_{\xi\theta}^{IV} - \sum_{M=I}^{III} t_{\xi\theta}^{M} = 0$$

$$\hat{f}_{\xi}^{IV} - \sum_{M=I}^{III} t_{\xi}^{M} \sin\psi^{M} - \sum_{M=I}^{III} \hat{f}_{\xi}^{M} \cos\psi^{M} + \overline{P} \cos\Phi_{0} = 0$$

$$m_{\xi}^{IV} - \sum_{M=I}^{III} m_{\xi}^{M} + \overline{M} = 0 \tag{86}$$

By recalling the definition of the y (Equation 48) and z (Equation 40) matrices and introducing the diagonal matrices

$$\beta = \begin{bmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & 0 \end{bmatrix} \qquad \eta = \begin{bmatrix} 0 & & & \\ & 0 & & \\ & & 0 & \\ & & & 1 \end{bmatrix} \tag{87}$$

Equations 65 and 86 may be recast in the formulas for compatibility

$$\beta z^{IV} + \eta y^{IV} = \beta\Psi^{I} z^{I} + \eta y^{I} = \beta\Psi^{II} z^{II} + \eta y^{II} = \beta\Psi^{III} z^{III} + \eta y^{III} \tag{88}$$

and for equilibrium

$$\beta y^{IV} + \eta z^{IV} = \sum_{M=I}^{III} \beta\Psi^{M} y^{M} + \eta z^{M} + \bar{\Phi}\overline{P} + \bar{\eta}\overline{M} \tag{89}$$

where

$$\bar{\Phi} = \begin{vmatrix} \sin\Phi_{0} \\ 0 \\ -\cos\Phi_{0} \\ 0 \end{vmatrix} \qquad \bar{\eta} = \begin{vmatrix} 0 \\ 0 \\ 0 \\ 1 \end{vmatrix} \tag{90}$$

Introducing Equations 36 into 88 and 89 and noting $\eta f = 0$; $\beta f = f$ and $\beta \Psi f = \Psi f$, we obtain:

for compatibility:

$$\eta H_{IV} \left(z^{IV}\right)' + \left(\eta J_{IV} + \beta\right) z^{IV} = \eta H_I z^{I'} + \left(\eta J_I + \beta \Psi^I\right) z^I$$
$$= \eta H_{II} z_{II}' + \left(\eta J_{II} + \beta \Psi^{II}\right) z^{II}$$
$$= \eta H_{III} z_{III}' + \left(\eta J_{III} + \beta \Psi^{III}\right) z^{III} \tag{91}$$

and for equilibrium

$$\beta H_{IV}\left(z^{IV}\right)' + (\beta J_{IV} + \eta) \cdot z^{IV} = \sum_{M=I}^{III} \left[\beta \Psi^M H_M z^{M'} + \left(\beta \Psi^M J_M + \eta\right) z^M + \Psi^M f_M\right] - f_{IV} + \overline{\Phi}\overline{P} + \overline{\eta}\overline{M} \tag{92}$$

A central finite difference scheme is used to obtain the numerical solution of Equations 91 and 92 within the framework of the Gaussian elimination procedure.

To eliminate the fictitious points (they will be used in calculating for internal forces and stresses at junction) z^I_{j+1}, z^{II}_{j+1}, z^{III}_{j+1} and z^{IV}_{j+1} that appear, we utilize the equilibrium equations at the ends of the adjoining regions of the juncture in a fashion similar to that used in the discontinuity section. After substituting the expressions for fictitious points in Equations 91 and 92 and recalling the definitions of the A, B, and C matrices (Equations 52), we may write the recursive equation equivalent of Equation 54 for the branched shell. As (for j^{IV}):

$$z_j^{IV} = - P_j^{IV} z_{j+1}^{IV} + X_j^{IV} \tag{93}$$

where

$$P_j^{IV} = L_M^{-1} \left\{ \frac{\beta H_{IV}}{2\Delta_{IV}} \left[I + C_{IV}^{-1} A_{IV}\right] - \left[\sum_{M=I}^{III} (K_M)\right] \left[\frac{\eta H_{IV}}{2\Delta_{IV}} I + C_{IV}^{-1} A_{IV}\right] \right\}$$

$$
\begin{aligned}
X_j^{IV} = L_M^{-1} \Bigg\{ \Bigg[\bigg[& \frac{\beta H_{IV}}{2\Delta_{IV}} C_{IV}^{-1} g_{IV} - f_{IV} + \sum_{M=I}^{III} \bigg| \beta\psi^{M} \frac{H_M}{2\Delta_M} A_M^{-1} g_M + \psi^{M} f_M \\
& - \frac{\beta\psi^{M} H_M}{2\Delta_M} \left[A_M^{-1} C_M + I \right] X_j^{M-1} \bigg| - \sum_{M=I}^{III} \bigg\{ (K_M) \bigg[\frac{\eta H_{IV}}{2\Delta_{IV}} C_{IV}^{-1} g_{IV} \\
& + \eta \frac{H_{IV}}{2\Delta_{IV}} A_{IV}^{-1} g_{IV} - \frac{\eta H_{IV}}{2\Delta_{IV}} \left[A_{IV}^{-1} C_{IV} + I \right] X_j^{M-1} \bigg] \bigg\} \Bigg\} \qquad (94)
\end{aligned}
$$

and

$$
\begin{aligned}
K_M = \bigg\{ & \frac{\beta\Psi^{M} H_M}{2\Delta_M} \left[- A_M^{-1} B_M + A_M^{-1} C_M P_j^{M-1} + P_j^{M-1} \right] \\
& + \left(\beta\Psi^{M} J_M + \eta \right) \bigg\} \; M_M^{-1} \\
L_M = \bigg\{ \bigg[& \left[(\beta J_{IV} + \eta) + \frac{\beta H_{IV}}{2\Delta_{IV}} C_{IV}^{-1} B_{IV} \right] - \sum_{M=I}^{III} K_M \bigg[\frac{\eta H_{IV}}{2\Delta_{IV}} C_{IV}^{-1} B_{IV} \qquad (95) \\
& + (\eta J_{IV} + \beta) \bigg] \bigg\}
\end{aligned}
$$

where

$$
M_M = \frac{\eta H_M}{2\Delta_M} \left[- A_M^{-1} B_M + A_M^{-1} C_M P_j^{M-1} + P^{M-1} \right] + (\eta J_M + \beta\psi^{M})
$$

For the remaining branch segments (i.e., M = I, II, III), the following recursion formula is used:

$$
z_j^{M} = Q_j^{M} \, z_j^{IV} + P_j^{M} \, z_{j+1}^{IV} + X_j^{M} \qquad (96)
$$

where

$$Q_j^M = M_M^{-1} \left\{ \frac{\eta H_{IV}}{2\Delta_{IV}} C_{IV}^{-1} B_{IV} + (\eta J_{IV} + \beta) \right\}$$

$$P_j^M = M_M^{-1} \left\{ \frac{\eta H_{IV}}{2\Delta_{IV}} \left[I - C_{IV}^{-1} A_{IV} \right] \right\}$$

$$X_j^M = M_M^{-1} \left\{ -\eta \frac{H_{IV}}{2\Delta_{IV}} C_{IV}^{-1} g_{IV} - \eta \frac{H_M}{2\Delta_M} A_M^{-1} \cdot g_M \right.$$

$$\left. + \frac{\eta H_M}{2\Delta_M} \left[A_M^{-1} C_M + I \right] X_j^{M-1} \right\}$$

and (M_M) is given by Equation 95.

Thus, from a knowledge of P_{j-1}^{I}, P_{j-1}^{II}, P_{j-1}^{III} - - -, P_{j-1}^{N-1} and X_{j-1}^{I}, X_{j-1}^{II}, - - -, X_{j-1}^{N-1}, the calculation can proceed directly to the determination of the Nth shell region, P_j^N, X_j^N and then to the boundary of branch N in the standard fashion.

APPENDIX IA: FORMULAS FOR COEFFICIENTS

The coefficients a_1, a_2 . . . a_{36} in Equation 38 are as follows:

$$a_1 = b$$

$$a_2 = \gamma b + b'$$

$$a_3 = \nu b' \gamma - \nu b \omega_\xi \omega_\theta - b\gamma^2 - \frac{(1-\nu) b n^2}{2\rho^2} - \lambda^2 d (1-\nu) \left[(1+\nu)\gamma^2 \omega_\xi^2 \right.$$

$$\left. + \frac{(3\omega_\xi - \omega_\theta)^2 n^2}{8\rho^2} \right]$$

$$a_4 = \frac{(1+\nu)bn}{2\rho} + \frac{\lambda^2 dn(1-\nu)}{8\rho}(3\omega_\xi - \omega_\theta)(3\omega_\theta - \omega_\xi)$$

$$a_5 = \frac{\nu nb'}{\rho} - \left(\frac{3-\nu}{2\rho}\right)(\gamma bn) - \frac{\lambda^2 d\,(1-\nu)\gamma n}{\rho}\left[\frac{(3\omega_\xi - \omega_\theta)(3\omega_\theta - \omega_\xi)}{8}\right.$$

$$\left. + (1+\nu)\omega_\xi\,\omega_\theta\right]$$

$$a_6 = b(\omega_\xi + \nu\omega_\theta) + \lambda^2 d(1-\nu)\left[(1+\nu)\gamma^2\omega_\xi + (n^2/2\rho^2)(3\omega_\xi - \omega_\theta)\right]$$

$$a_7 = b\left[\omega_\xi' + \gamma(\omega_\xi - \omega_\theta)\right] + b'(\omega_\xi + \nu\omega_\theta)$$

$$- \frac{\lambda^2 d\,(1-\nu)\gamma n^2}{\rho^2}\left[\frac{3\omega_\xi - \omega_\theta}{2} + (1+\nu)\omega_\xi\right]$$

$$a_8 = \lambda^2\omega_\xi$$

$$a_9 = \lambda^2(1-\nu)\gamma\omega_\xi$$

$$a_{10} = -a_4$$

$$a_{11} = \frac{b\gamma n}{2\rho}(3-\nu) - \frac{(1-\nu)nb'}{2\rho} + \frac{\lambda^2 d(1-\nu)n}{\rho} \times \left[-(1+\nu)\gamma\,\omega_\xi\,\omega_\theta\right.$$

$$\left. + \frac{\gamma}{8}(6\omega_\xi\,\omega_\theta - 7\omega_\xi^{\,2} - 3\omega_\theta^{\,2}) - \frac{\omega_\xi'}{4}(5\omega_\theta - 3\omega_\xi)\right]$$

$$- \frac{\lambda^2 d'\,(1-\nu)\,n}{8\rho}(3\omega_\xi - \omega_\theta)(3\omega_\theta - \omega_\xi)$$

$$a_{12} = \frac{b\,(1-\nu)}{2} + \frac{\lambda^2 d\,(1-\nu)\,(3\omega_\theta - \omega_\xi)^2}{8}$$

$$a_{13} = \left(\frac{1-\nu}{2}\right)(\gamma b + b') - \frac{\lambda^2 d\,(1-\nu)}{8}(3\omega_\theta - \omega_\xi) \times \left[2\omega_\xi' - \gamma(5\omega_\xi - 3\omega_\theta)\right]$$

$$+ \frac{\lambda^2 d'\,(1-\nu)}{8}(3\omega_\theta - \omega_\xi)^2$$

$$a_{14} = -\gamma a_{13} + \left(\frac{1-\nu}{2}\right) b\omega_\xi \omega_0 - \frac{bn^2}{\rho 2} - \lambda^2 d\,(1-\nu)\left[\frac{(1+\nu)\omega_\theta{}^2 n^2}{\rho^2}\right.$$

$$\left. - \frac{\omega_\xi \omega_0}{8}\,(3\omega_0 - \omega_\xi)^2\right]$$

$$a_{15} = \frac{\lambda^2 d\,(1-\nu)\,(3\omega_\theta - \omega_\xi)n}{2\rho}$$

$$a_{16} = \frac{\lambda^2 d\,(1-\nu)n}{2\rho}\left|2\,(1+\nu)\gamma\omega_\theta - \omega_\xi{}' + 3\gamma(\omega_\xi - \omega_\theta)\right|$$

$$+ \frac{\lambda^2 d'\,(1-\nu)\,(3\omega_\theta - \omega_\xi)n}{2\rho}$$

$$a_{17} = -\frac{bn\,(\omega_\theta + \nu\omega_\xi)}{\rho} + \frac{\lambda^2 dn\,(1-\nu)}{2\rho} \times \left|\gamma\omega_\xi{}' - 2\gamma^2\omega_\xi\right.$$

$$\left. - \frac{2\,(1+\nu)\omega_\theta n^2}{\rho 2} + (3\omega_\theta - \omega_\xi)\,(\gamma^2 + \omega_\xi\omega_\theta)\right|$$

$$- \frac{\lambda^2 d' n\,(1-\nu)\gamma}{2\rho}(3\omega_\theta - \omega_\xi)$$

$$a_{18} = -(\nu\lambda^2\omega_\theta n/\rho)$$

$$a_{19} = -a_6$$

$$a_{20} = -b\gamma(\omega_\theta + \nu\omega_\xi) + \lambda^2 d\,(1-\nu)\left|\gamma(1+\nu)\,(-\gamma\omega_\xi{}'\right.$$

$$+ \gamma^2\omega_\xi - (n^2\omega_\xi/\rho^2) + 2\omega_\xi{}^2\omega_\theta) + (n^2/2\rho^2)\,(\gamma\ {}_\xi$$

$$\left. - \gamma\omega_\theta - 3\omega_\xi{}')\right| - \lambda^2 d'\,(1-\nu)\left|(1+\nu)\gamma^2\omega_\xi\right.$$

$$\left. + (n^2/2\rho^2)\,(3\omega_\xi - \omega_\theta)\right|$$

$$a_{21} = a_{15}$$

$$a_{22} = \frac{\lambda^{2} d\ (1-\nu)\ n}{2\rho} \left| 3\gamma\omega_{\xi} - \gamma\omega_{\theta}\ (5+2\nu) - \omega_{\xi} \right|$$

$$+ \frac{\lambda^{2} d'\ (1-\nu)\ n}{2\rho} (3\omega_{\theta}\ \ \omega_{\xi})$$

$$a_{23} = - \frac{bn\ (\omega_{\theta} + \nu\omega_{\xi})}{\rho} + \frac{\lambda^{2} d\ (1-\nu)\ n}{2\rho} \times \left| 2\ (1+\nu) \left(\omega_{\xi}\omega_{\theta}^{2} - \gamma^{2}\omega_{\xi} \right. \right.$$

$$\left. \left. + 2\gamma^{2}\omega_{\theta} - \frac{n^{2}\omega_{\theta}}{\rho^{2}} \right) + \gamma\omega_{\xi}' + 3\gamma^{2}\ (\omega_{\theta} - \omega_{\xi}) + \omega_{\xi}\omega_{\theta}\ (3\omega_{\theta} - \omega_{\xi}) \right|$$

$$- \frac{\lambda^{2} d'\ (1-\nu)\ n}{2\rho} \left| 2\ (1+\nu)\gamma\omega_{\theta} + \gamma(3\omega_{\theta} - \omega_{\xi}) \right|$$

$$a_{24} = \lambda^{2} d\ (1-\nu) \left| (2n^{2}/\rho^{2}) + (1+\nu)\gamma^{2} \right|$$

$$a_{25} = - \lambda^{2} d\ (1-\nu) \left| (1+\nu)\ (2\gamma\omega_{\xi}\omega_{\theta} + \gamma^{3}) + (2\gamma n^{2}/\rho^{2}) \right|$$

$$+ \lambda^{2} d'\ (1-\nu) \left| (1+\nu)\ \ ^{2} + (2n^{2}/\rho^{2}) \right|$$

$$a_{26} = -b(w_{\xi}^{2} + 2\nu\omega_{\xi}\omega_{\theta} + \omega_{\theta}^{2}) + \frac{\lambda^{2} d\ (1-\nu)\ n^{2}}{\rho^{2}} \left[(1+\nu) \left(\omega_{\xi}\omega_{\theta} - \frac{n^{2}}{\rho^{2}} + 2\gamma^{2} \right) \right.$$

$$\left. + 2\ (\gamma^{2} + \omega_{\xi}\omega_{\theta}) \right] \cdot \frac{\lambda^{2} d'\ (1-\nu)\ n^{2}}{\rho^{2}} (3+\nu)\gamma$$

$$a_{27} = \lambda^{2}$$

$$a_{28} = \lambda^{2}\gamma\ (2-\nu)$$

$$a_{29} = - \lambda^{2} \left| (1-\nu)\omega_{\xi}\omega_{\theta} + (\nu n^{2}/\rho^{2}) \right|$$

$$a_{30} = d\omega_{\xi}$$

$$a_{31} = d\ (\omega_{\xi}' + \nu\gamma\omega_{\xi})$$

$$a_{32} = d\nu n\ \omega_{\theta}/\rho$$

$a_{33} = - d$

$a_{34} = - d\nu\gamma$

$a_{35} = d\nu n^2/\rho^2$

$a_{36} = - 1$

The c's are

$$c_1 = - p_\xi + t_T' - \lambda^2 (1-\nu)\gamma\omega_\xi \, m_T$$

$$c_2 = - p_\theta - (n/\rho) t_T - \lambda^2 (1-\nu) (n/\rho)\omega_\theta \, m_T$$

$$c_3 = - p - (\omega_\xi+\omega_\theta) t_T - \lambda^2 (1-\nu) \gamma m_T' + \lambda^2 (1-\nu)\left[\omega_\xi \omega_\theta - (n^2/\rho^2)\right] m_T$$

$$c_4 = m_T$$

Finally, the b's in Equation (49) are

$$b_1 = b$$

$$b_2 = \nu\gamma b$$

$$b_3 = \nu n b/\rho$$

$$b_4 = b\,(\omega_\xi + \nu\omega_\theta)$$

$$b_5 = -\frac{b\,(1-\nu)\,n}{2\rho} - \frac{d\lambda^2\,(1-\nu)\,n}{8\rho}(3\omega_\xi - \omega_\theta)\,(3\omega_\theta - \omega_\xi)$$

$$b_6 = \frac{b\,(1-\nu)}{2} + \frac{\lambda^2 d\,(1-\nu)}{8}(3\omega_\theta - \omega_\xi)^2$$

$$b_7 = - \gamma b_6$$

$$b_8 = \frac{\lambda^2 d\,(1-\nu)\,n}{2\rho}(3\omega_\theta - \omega_\xi)$$

$$b_9 = - \gamma b_8$$

$$b_{10} = - \lambda^2 d\,(1-\nu) \left| (1+\nu)\,\gamma^2 \omega_\xi + (n^2/2\rho^2)\,(3\omega_\xi - \omega_\theta) \right|$$

$$b_{11} = \frac{\lambda^2 d\,(1-\nu)\,n}{2\rho}\,(3\omega_\theta - \omega_\xi)$$

$$b_{12} = - \frac{\lambda^2 d\,(1-\nu)\,\gamma\,n}{2\rho} \left| 3\omega_\theta - \omega_\xi + 2\,(1+\nu)\omega_\theta \right|$$

$$b_{13} = \lambda^2 d\,(1-\nu) \left| (2n^2/\rho^2) + (1+\nu)\,\gamma^2 \right|$$

$$b_{14} = - \lambda^2 d\,(1-\nu)\,(3+\nu)\,(\gamma n^2/\rho^2)$$

$$b_{15} = \lambda^2$$

$$b_{16} = \lambda^2\,(1-\nu)\gamma$$

PAGES 40 AND 41 ARE MISSING FROM THE ORIGINAL DOCUMENT.

paragraphs that follow are intended to aid in formulation of the problem for program use and augment the detail input instructions in Section III. For ease of reference, FORTRAN instruction symbols used in the program and related to the descriptive paragraphs are placed in parentheses following paragraph titles.

2.2 PROGRAM CAPABILITIES AND LIMITATIONS

Before describing some of the general program characteristics, it will perhaps be worthwhile to list some of the program features that are not generally present in other shell analysis programs. Also included in this list are limitations in the program that have resulted due to theoretical restrictions, computer storage capacity, economic considerations, etc.

a. A shell structure having virtually any combination of abrupt discontinuities in geometry, loads, temperature, and material properties can be analyzed by breaking the structure into the appropriate regions.

b. The main requirement in each shell region is that geometry, material properties, loads, and temperatures vary smoothly along the generatrix or meridian line.

c. As many as 50 (estimated) integrally joined shell regions can be analyzed as one shell structure.

d. As many as four regions may be joined at one common junction (branch point).

e. Line loads and line moments can be applied at junctions between regions. The effects of eccentricity of reference surfaces occurring at discontinuity junctions (juncture of two shell regions) is automatically handled by the program. At branch points, these effects can be handled by an approximate procedure or minimized by appropriate selection of junction point.

f. Laminated shell structures consisting of up to three materials broken into as many as six intimately bonded layers can be considered by the computer program.

g. All materials excepting Poisson's ratio can vary from layer to layer through the thickness as well as along the meridional coordinate.

h. As many as 150 integration intervals (station points) can be considered in each region.

i. Curve fitting techniques are utilized to reduce amount of input data. A second-degree polynomial fit is used.

j. Both unsymmetric surface load and temperatures can be applied to the shell. The variation of temperature across the cross-section can be continuous and piece-wise linear through each layer.

k. The numerical solution procedure allows for high accuracy without excessive use of computer time. (Approximate machine running time 150 stations per minute for each Fourier harmonic.)

2.3 SIGN CONVENTIONS AND DIMENSIONS

The sign conventions used in the program are illustrated in Figures 1-1 through 1-10 in Section I. To briefly augment, the stresses σ_ξ, σ_θ and membrane forces N_ξ, N_θ are positive when they tend to produce tension and negative when they are in compression. The moments M_ξ, M_θ are positive in sign when they tend to produce tensile stresses in the inner (bottom) surfaces and compressive stresses in the outer (top) surface. (See Section 2.4.) The extensional displacement u and transverse deflection w are positive when the ξ and ζ coordinates, respectively, are increased.

In using the program, all data specified must be dimensionally consistent. In the manual, the quantity P will indicate force quantities (e.g., pounds) and L length quantities (e.g., inches). The program output yields results in force and length that are consistent with the input quantities.

2.4 REFERENCE, INNER, AND OUTER SURFACES

The reference surface $\zeta = 0$ is chosen such that the requirements of Equation 1 be satisfied. The cross-sectional properties are then evaluated based upon this reference surface. As discussed in 1.15, a substantial simplification is obtained when specifying key geometric functions (e.g., r, ω_ξ). if the reference surface is chosen according to convenience anywhere within the shell wall. However, the shell stiffness parameter should be evaluated systematically along the lines discussed in Section I.

It will be convenient to refer to inner and outer surfaces of the shell. One can keep the inner and outer surface definitions clear by remembering that in direction of increasing value of ξ, the outer surface is on the left and the inn[illegible] on the right when the geometry is drawn with axial distance in[illegible] fr[illegible] to bottom and radial distance from left to right as shown in Figure 1-1. Using the same description, the inner surface will sometimes be referred to as the "bottom" (BOT) surface and outer as the "top" (TOP) surface.

2.5 SHELL REGIONS (EKK)

In solving a shell problem it is necessary to select a mathematical model to represent the actual shell configuration. It may be necessary or convenient in establishing a suitable mathematical model for complicated shell configurations to fictitiously divide the shell along its length into a number of "regions." Thus, the first step in the analysis of shell problems is to delineate the "regions" of the mathematical model. Ideally, this division results in each region being a simple shell element, such as a cylinder, sphere, cone, etc.

The main requirement in delineating a shell region is that shell properties and loads vary smoothly along the generatrix or meridian line in the region. Thus, the logical dividing line between regions would occur at points on the shell where an abrupt discontinuity or a radical change in any of the following exists: (1) geometry; (2) section or material properties; (3) induced or surface loading; (4) temperature distribution; (5) other considerations such as length to radius magnitudes; (6) combinations of 1 through 5. The points at which these fictitious subdivisions occur are called junctions. It will be convenient in the program to differentiate between two types of junction points. The point where one region of the mathematical model is joined to a single other region of the same mathematical model is termed a discontinuity point or junction. (See Section 1.11.) Junctions where more than two shell regions meet at a common point are called branch points. (See Section 1.16.) It should be emphasized that it is absolutely essential in treating problems where abrupt discontinuities in shell properties (1 and 2 above) occur to introduce a junction point since a unique solution procedure is required in such cases. For convenience of data input or change in grid increment (Section 1.12), fictitious-type discontinuities may be introduced when desirable.

Theoretically, the limit on the number of shell regions per problem is dictated by the storage capacity on the tapes used. Twenty regions have been used without diffic y, and it is estimated that the capability for considering up to 50 regions is possible. With a structural mesh of 150 grid points possible (Section 2.7), it is unlikely that such a large number of regions is necessary in treating even the most complicated of engineering problems.

The program code processes the region data in the order in which the regional data is introduced into the input data deck of punched cards. The first region is known as region 1, the second region, regions 2, etc., even though punched cards do not carry the number designation of the regions. The complete data information for a particular region must be inputted before the subsequent region data can be considered. The sequence of input of regional data must be consistent with the analytical solution of the problem. The regions should be selected in sequence proceeding in a continuous manner from one boundary to the final boundary. The procedure for handling branched shell configurations (more than two shells joining) is modified somewhat in that data for each branch is input up to one common branch junction point until the next to last branch is completed. The data for the final or closing branch proceeds from junction point to the final end conditions. (See 2.10.2.)

The code value EKK represents the number of shell regions selected for a particular shell problem. The amount of regional data must coincide with the value of EKK. The examples shown below indicate typical region delineation for complicated shell configurations.

In Figure 2-1 a five-region shell configuration is shown where four discontinuity junctions have been used to subdivide the mathematical model. Junction ① illustrates a discontinuity point where an abrupt change in the shell section properties occur. A discontinuity of slope between the reference surface of two joining shells is illustrated by junction ②. At ③ and ④, fictitious subdivisions have been introduced where abrupt changes in load distribution occurred. The arrows on Figure 2-1 indicate the direction of increasing ξ or station number and the sequence of data input. A six-region branched shell is shown in Figure 2-2. The first discontinuity point illustrates the region delineation when two shells of different shapes meet. Branch points ② and ③ represent common branch points where more than two regions join. This example will be discussed in more detail in Section 2.10 on junction points.

2.6 FOURIER COMPONENTS (SUM, ENFO, ENFI, ENFOR, THETA)

The computer program permits analysis of shells subjected to unsymmetric loads using a Fourier series technique. This approach described in Section 1.7 permits the analysis of complicated loads by considering the individual contribution of each Fourier component of the Fourier series expansion of the load distribution. The total solution is obtained by summing the Fourier components in the appropriate series expression in the circumferential coordinate.

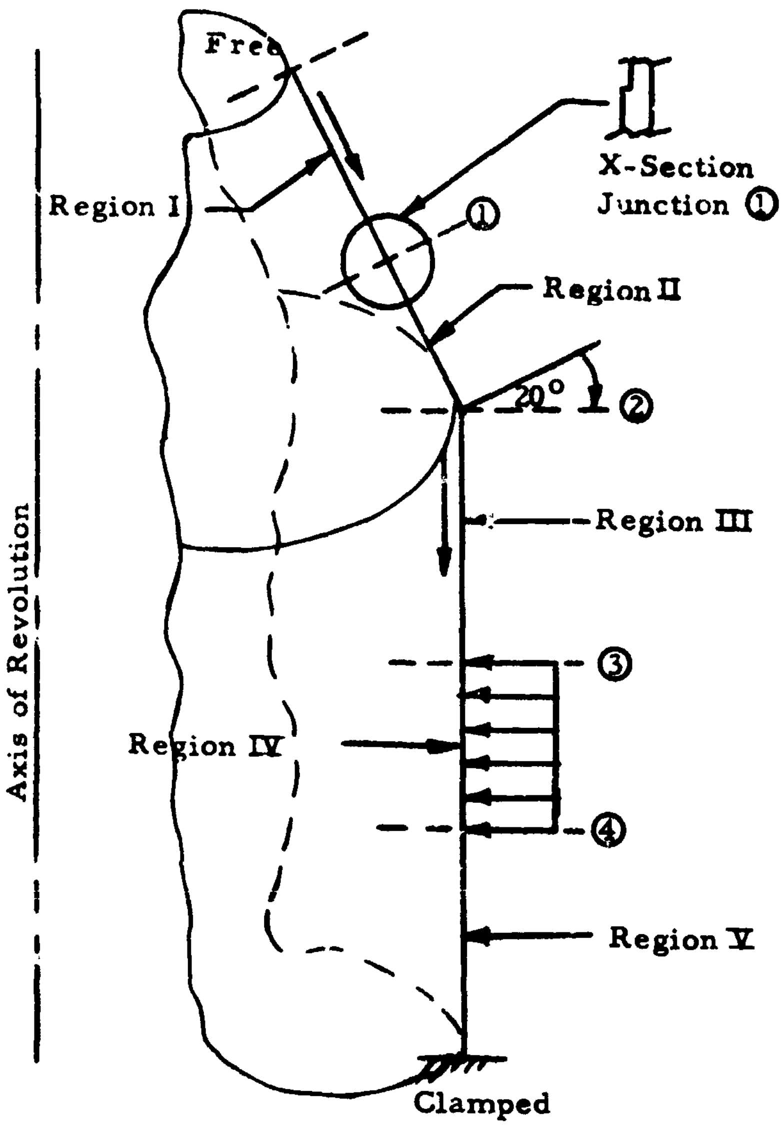


Figure 2-1

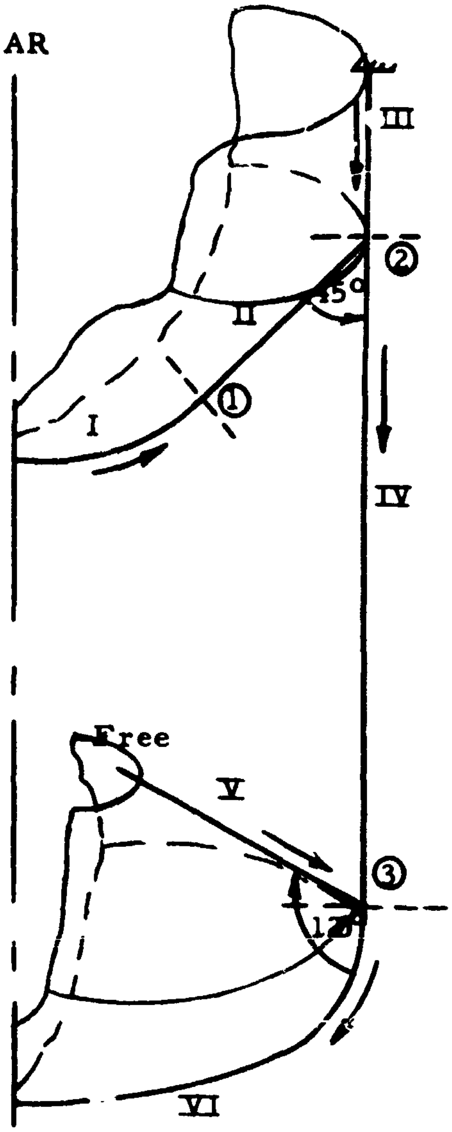


Figure 2-2

When treating more than one Fourier component for a shell problem the code value SUM is set to a nonzero value. A positive value for the SUM indicator indicates the solution will be summed according to the series expressions, Equations 1[illegible] through 24, page 7. A negative SUM prints the individual solution for each discrete Fourier harmonic.

The data value ENFO represents the first and lowest Fourier harmonic (ENF) considered. Subsequent Fourier components are numbered in increasing order in the ENFI(I) data region. Up to 11 ENF values are permissible in this data region. If more than 11 Fourier harmonics are to be considered, the problem can be reformulated for the remaining harmonics and the solutions added.

It may be desirable to test the convergence of the Fourier series solution to obtain intermediate prints of partial Fourier sums. This capability is possible using the ENFOR(I) data region where these intermediate prints are permissible. For example, if 10 Fourier components are considered, it might be desirable to print the summed solutions for the last three harmonics to compare convergence of results.

In order to determine the value of solution at circumferential (THETA) locations on the shell, the capability for evaluating the series expressions at discrete THETA values is possible. This data region THETA(I) permits a maximum of 10 circumferential solution printouts.

2.7 STATIONS IN REGIONS (EN)

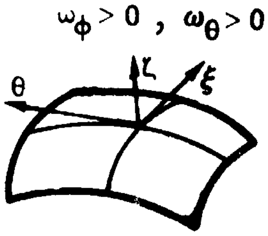
The machine program achieves a shell solution by integration of finite difference equations along the meridian or arc length distance of the shell. The meridional coordinate ξ on the reference surface has the range $0 \le \xi \le \xi_j$ for the j-th region. The number of integration points (called stations) located in the region under consideration is assigned the EN code value. The stations are equally spaced with the initial point located on the reference surface at the beginning of the region designated station 1 ($i = 1$ or $\xi = 0$) and the last or EN-th station at the end of the region called station N ($i = N$ or $\xi = \xi_j$). The numbering of stations proceeds in direction of positive meridional coordinate assigned to the respective region. The maximum number of stations permissible in a region is 150 (minimum 3). The regional input data are specified at stations on the reference surface of each region.

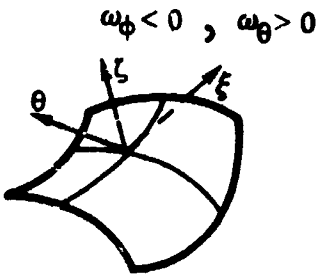
The length of the finite difference "lump" of shell is computed internal to the program from the length or wrap distance and the number of stations (EN) in the region. This finite difference increment of integration is defined as DEL in the program and printout. Best results are obtained when the finite difference increments are approximately the same from region to region.

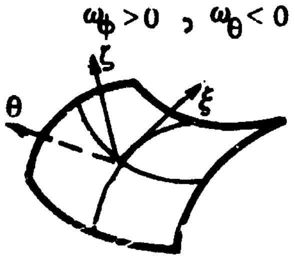
The machine running time increases with the number of integration steps considered per region. The type of shell problem considered should dictate the size of the grid mesh or number of stations considered. This comes with experience and how the results are to be used. As a general rule, it is recommended that more integration intervals be used where rapid change in variables occurs along the length of the shell. Experience with the program indicates that considering 100 stations is probably sufficient for engineering type accuracy of the shell solution in most shell regions. For extremely long shells (e.g., cylinders), it may be necessary to subdivide the shell into more regions in order to obtain a suitable integration interval.

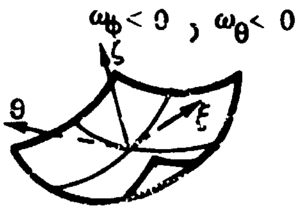
2.8 GEOMETRY OF REGIONS (GMI)

Geometric parameters must be defined at each station location. The sign convention for the curvature parameters, ω_ϕ, ω_θ are illustrated as follows:









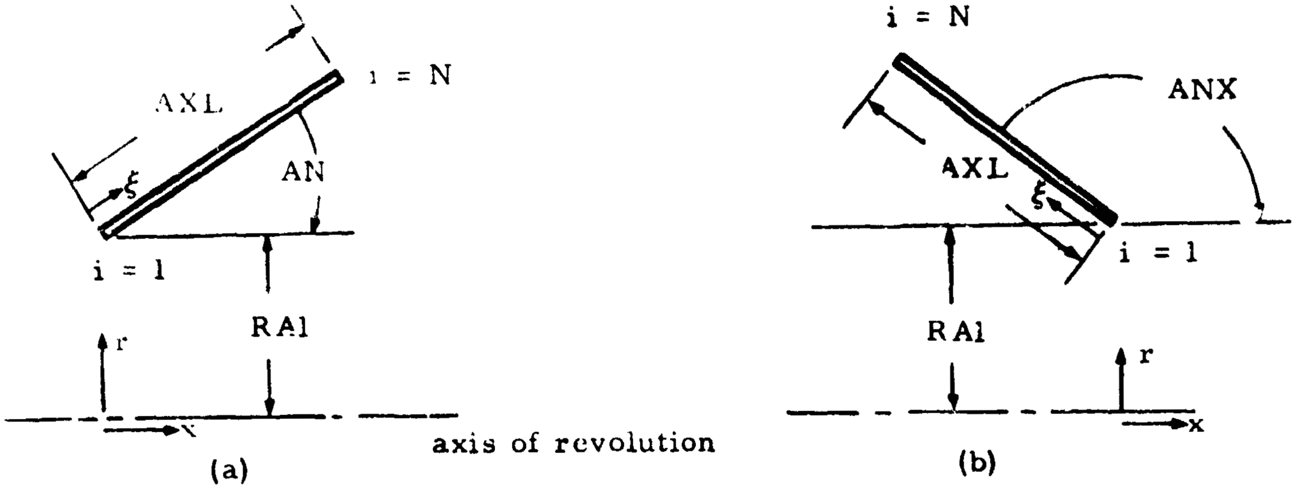
In order to assist the analyst in defining the set of geometry parameters with a minimum number of input parameters, several options for specific classes of geometries are made available. The options are described below with their identifying code number (GMI).

2.8.1 Cone-Cylinder Option (GMI = 1.0)

This geometry option may be specified for a complete range of regional configurations generated by a straight line, e.g., circular plates, cones, and cylinders. A minimum of three input parameters is required. The input parameters required are defined as follows:

1. RA1 - Radial distance from axis of revolution to the first station ($i = 1$) of the region
2. AXL - meridional length of shell
3. ANX - angle the generator makes with the axis of revolution

Figure 2-3 illustrates the geometric parameters used in describing the cone cylinder option. Both RA1 and AXL are positive quantities. The parameter ANX is given in degrees and is positive clockwise measured from the generator to the positive X axis as shown in Figure 2-3.



(a) (b)

Figure 2-3. Cone Cylinder Geometry

2.8.2 Sphere-Toroid (GMI = 2.0)

This option may be specified for a complete range of regional configuration generated by a circular curve. Four input parameters are necessary for defining a sphere-toroid, as shown in Figure 2-4.

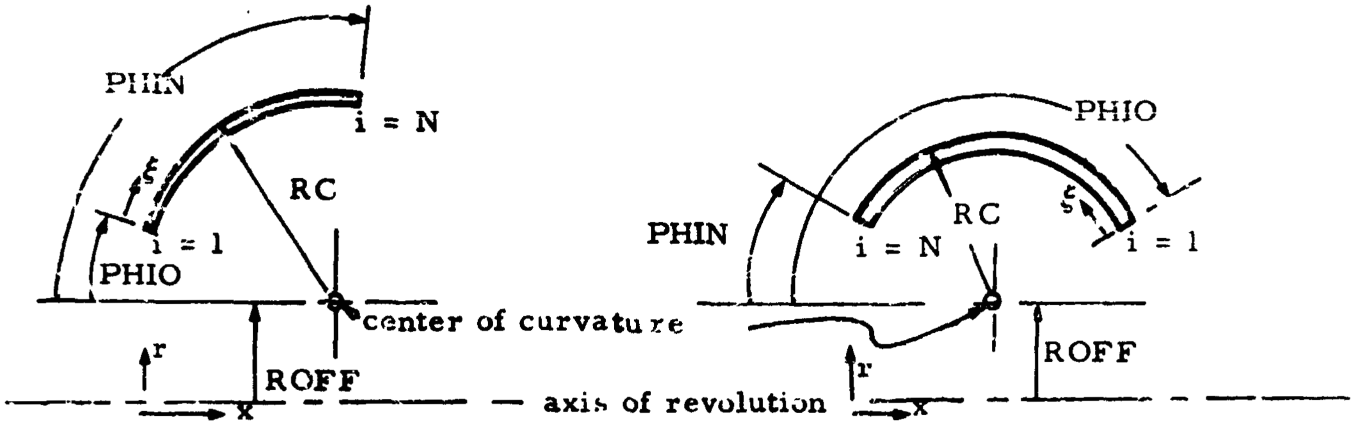


Figure 2-4. Sphere-Toroid Geometry

The input parameters are

1. RC - Radius of curvature of the generator

2. ROFF - Offset distance measured from axis of revolution to the center of meridional curvature

3. PHIO - Angular position in degrees of the beginning of a region measured clockwise positive about the center of curvature from an axis parallel to the axis of revolution

4. PHIN - Angular position of the end of the region

2.8.3 Discrete Point Option (GMI = ±3.0)

This option was developed for use on regions where the generator cannot be described by one of the other options or where a curved generator is given by a set of discrete points. As a consequence of various possible ways the geometry may be supplied to the analyst, several variations of input data format can be accommodated.

On a positive indicator (GMI = +3.0), the program will set up the necessary geometric parameter from the input data which describes the generator by discrete radial and axial distances. The input quantities to the program are EM (number of points given), RIPT (radial distance from axis of revolution at input points), XIPT (axial coordinates of the input points). The set of RIPT and XIPT must include the first and last points of the region. XIPT must be given in ascending magnitudes. On a negative indicator (GMI = -3.0), the coordinates of the discrete points are given in radial and surface or arc length, the surface length coordinate is input directly in the XIPT locations.

An interpolation routine is used to obtain appropriate geometric parameters at station points from the original input values. The parameters such as curvatures are computed using finite difference forms of the station set. A least squares method is used to minimize the scatter of these computations. To hold the errors in curvatures to less than 10 percent, the number of points described by RIPT and XIPT should be at least as great as the number of stations. For some situations such as locations of major changes in the generator curve, it will be necessary to input a denser population of RIPT and XIPT. (See Figure 2-5.) Because of the difficulty involved in the least squares and interpolation routines, extreme care must be exercised in the use of this option in order to obtain an adequate description of shell geometry. A significant improvement in results is obtained if the additional recommendations described below are adhered to.

When the meridional and circumferential radii of curvatures are available, they can be input at discrete points and curve-fit to give a better description of the curvatures. If possible, it is strongly recommended that this capability be used since the errors in curvatures are reduced considerably to better control curvatures and less input points of the generator

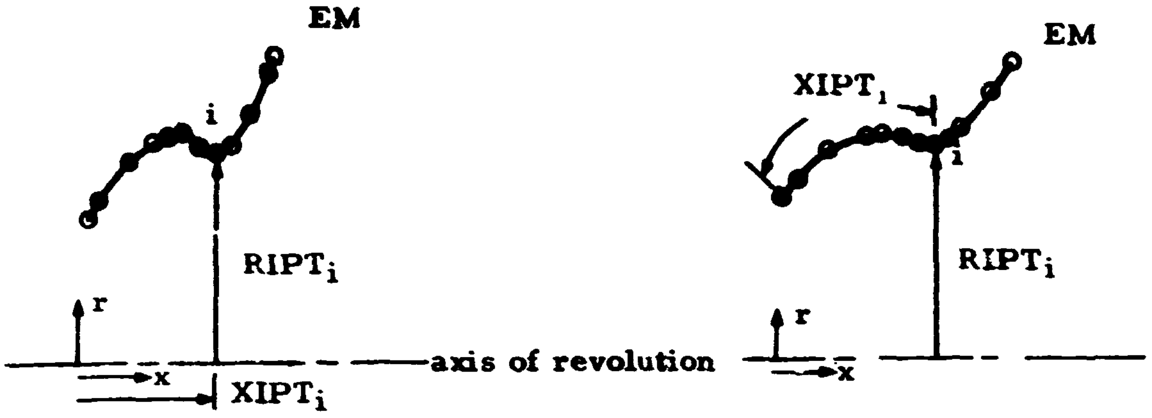


Figure 2-5

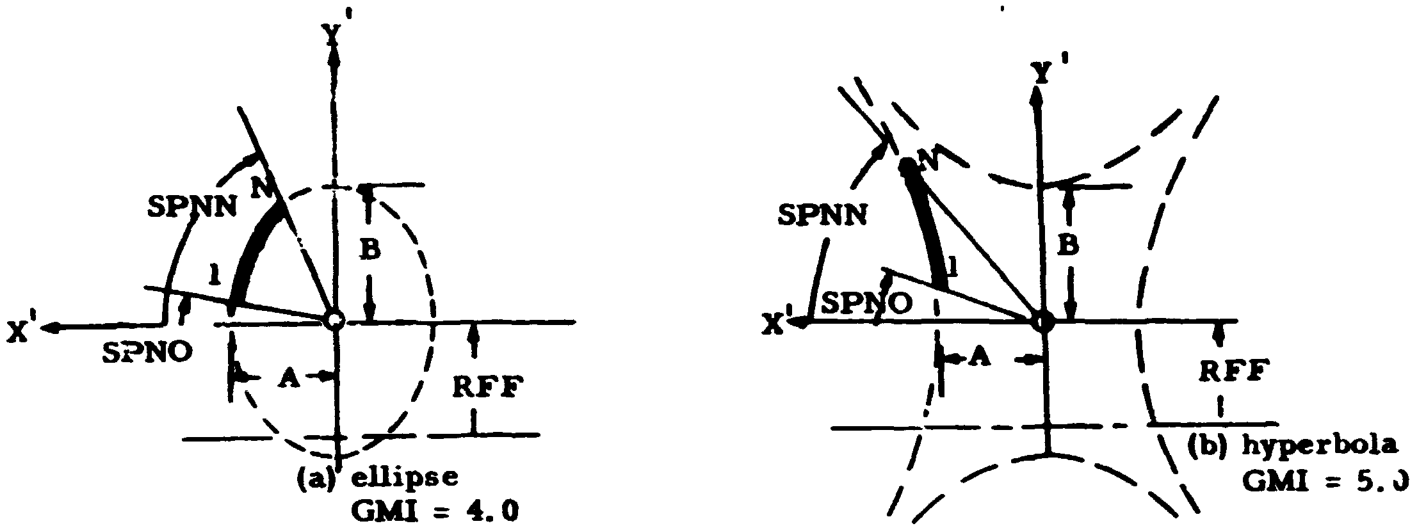
are required. This data is input in the location RCURV and RCURZ for radius of curvatures R_ξ and R_θ, respectively (Section 1.3). RCURV and RCURZ values must correspond with the points described by RIPT and XIPT. This is an optional input to both GMI = +3.0 and GMI = -3.0. When no values are input at RCURV and RCURZ locations, the curvatures will be computed from the discrete point set of RIPT and XIPT.

2.8.4 Conics Options (GMI = 4.0, 5.0, ±6.0)

Several options are made available for the conics class of generator. Three classes of conics are treated: ellipse (GMI = 4.0), hyperbola (GMI = 5.0), and the parabolas (GMI = ±6.0). The parameters for the conics are taken from the standard form (Figure 2-6).

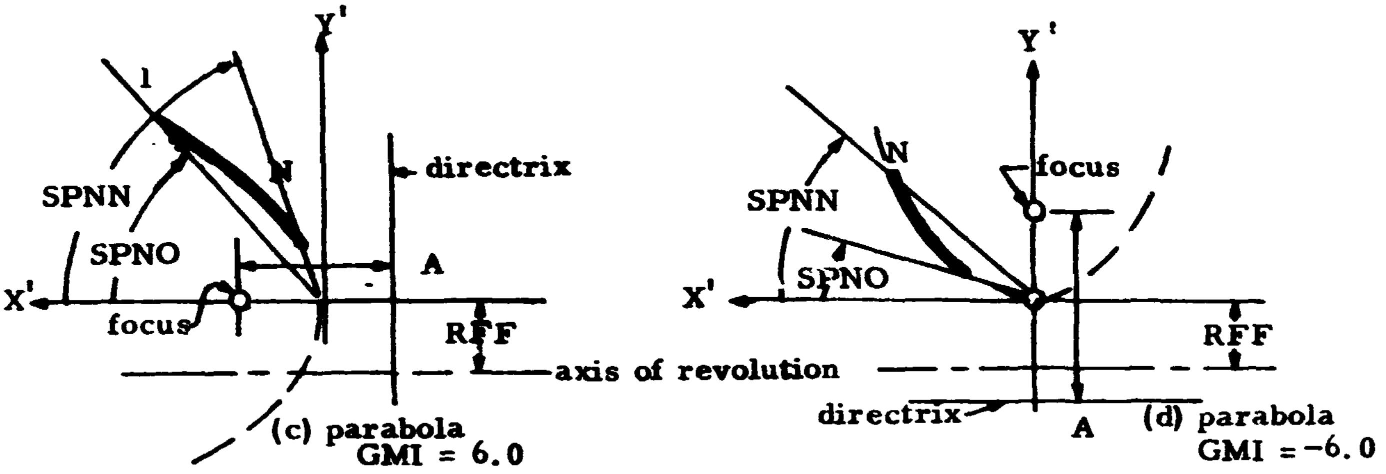
In Figure 2-6, the coordinates X', Y' are the standard form coordinates. The input quantities are as follows:

1. RFF is the translation distance of X' axis from the axis of revolution.
2. SPNO is the clockwise positive opening angle from positive X' to the first station location.
3. SPNN is the positive opening angle from positive X' to the last station location.



(a) ellipse
GMI = 4.0

(b) hyperbola
GMI = 5.0



(c) parabola
GMI = 6.0

(d) parabola
GMI = -6.0

Figure 2-6

4. A is the semimajor axis parallel to the axis of revolution for the ellipse and hyperbola. A is the distance from the directrix to the focus for the parabolas.

5. B is the semimajor axis perpendicular to the axis of revolution.

2.9 END CONDITIONS (BCITP, BCIBM)

Four boundary or end conditions must be supplied at each end of a shell region. From Section 1.9, these conditions are input in matrix form. To simplify the amount of data input a boundary indicator code has been set up to permit simple call of boundary support conditions. The value BCITP defines the boundary indicator at the 1st or top station (i = 1) of the region and BCIBM the value at the last station (bottom) (i = N). The boundary or end conditions permitted by the code, together with the identifying code number and mathematical description, are as follows:

BCITP or BCIBM Code No.	Type of End Condition	Mathematical Equivalent
1	Free Support	$t_\xi = \hat{t}_{\xi\theta} = \hat{f}_\xi = m_\xi = 0$
2	Roller	$t_\xi = u_\theta = w = m_\xi = 0$
3	Clamped (Fixed)	$u_\xi = u_\theta = w = \phi_\xi = 0$
4	Simple Support (Hinged)	$u_\xi = u_\theta = w = m_\xi = 0$
5	Symmetrical (or Complete)*	$u_\xi = u_\theta = \hat{f}_\xi = \phi_\xi = 0$
6	Special	Read Boundary Matrices Ω, Λ, ℓ
7, 8	(to be defined)	Space for additional Boundary Condition
9	Closed Apex (r = 0)	See Section 1.10 for conditions
10	Branch Point	
0, >10	Discontinuity Point	

The identifying boundary matrices for often encountered external support conditions 1 through 5 and 9 are internal to the program and can be called by stipulating the correct code number. Space is available in code numbers 7 and 8 to put in appropriate boundary condition matrices that offer particular interest to the user. Specifying BCITP (or BCIBM) = 6 permits inputting boundary matrices Ω, Λ, and ℓ (See Equation 47) directly into the program. This option would be used when considering special boundaries, spring support conditions, applied load or displacements to boundaries, or any consistent set of end restraint conditions. The details

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*Special condition when shell has a plane of symmetry about the normal to the axis of revolution. Use only for axisymmetric loads (e.g., complete sphere can be treated as hemisphere).

of formulating these matrices directly are described in Section 3.4.5. The indicator value when set equal to 0 (or >10) indicates a discontinuity condition occurring at the particular boundary location. The program automatically employs the appropriate compatibility relationship as described in Section 1.11. When the endpoint corresponds to a branched junction point (more than two shells coming together), the boundary indicator must be set at 10 and the program will automatically set the solution format to handle branched configurations.

2.10 JUNCTIONS (GPSI, GECX, PD, MD, PSIO)

A junction occurs when one region of the mathematical model is joined to one, two, or three regions of the same mathematical model. It will be convenient to differentiate between two types of junction points. A detailed description of discontinuity and branch type junction points is given in the following paragraphs. Each type requires a different mode of solution in the computer program (Section 1.11 and 1.16). Also discussed below is a description of external line loads and moments that can be applied at junction points.

2.10.1 Discontinuity Junction

By our definition, a discontinuity junction occurs at a point where one region of the mathematical model is joined to another single region of the same mathematical model. Discontinuity junctions are usually selected where abrupt discontinuities in shell properties or loads occur. However, fictitious type discontinuities are sometimes introduced where change in finite difference grid interval is described or for reasons of convenience of inputting data. Types of abrupt discontinuities in shell properties that can be accommodated by the program are illustrated by considering in detail the example shown in Figure 2-7.

Junction ② (Figure 2-7a) illustrates a discontinuity point occurring between regions II and III due to an abrupt angle change in reference surface caused by two shells of different shape joining at a common point. The angle ψ is coded GPSI in the program and measures the change in slope, i.e., the angle between the normals to the region meridians at the junction point. The discontinuity angle GPSI is referred to the end of the region, e.g., the ψ in Figure 2-7a would be part of the input data of region II. The discontinuity junction ① characterizes a discontinuity point where an abrupt change in the shell cross-sectional (including material) properties occurs. The program will also accommodate eccentric discontinuities, i.e., discontinuities where reference surfaces at a discontinuity junction do not intersect at a common point (see Figure 2-7b). The program automatically compensates for the couple generated by in-plane membrane forces in each region

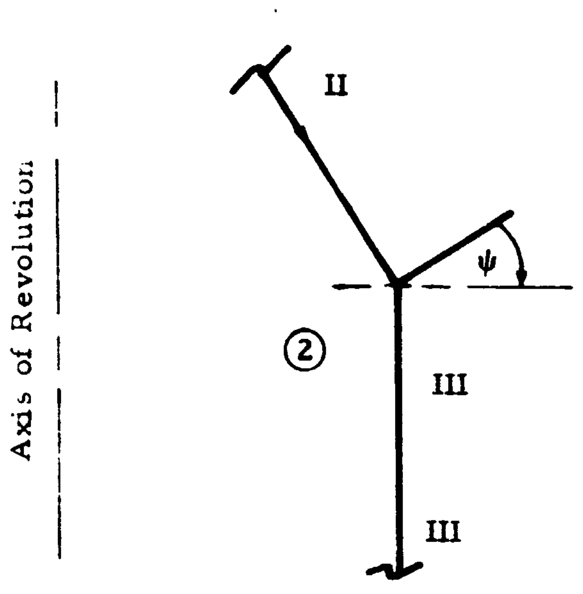


Figure 2-7a. Slope Discontinuity (Discontinuity Junction 2 of Figure 2-1)

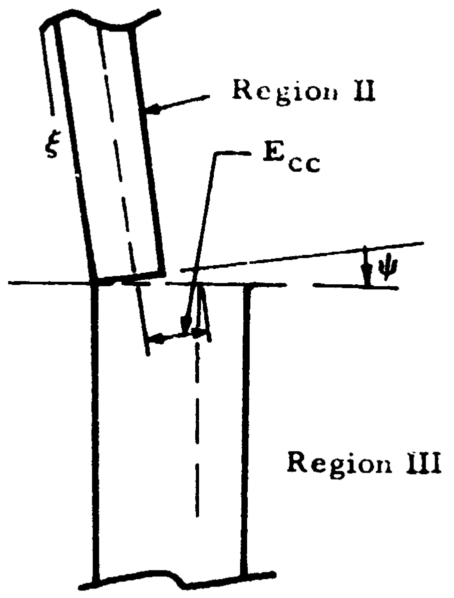


Figure 2-7b. Eccentric Discontinuity (Junction 1 of Figure 2-1)

not being coincident with each other. The eccentricity distance E_{cc} (Figure 2-7b) is coded GECX and represents the eccentricity of reference surfaces measured along the radius of curvature at the end point of a region (e.g., region II of Figure 2-7b). A positive value of E_{cc} corresponds to an abrupt increase in the radius of a parallel circle as one proceeds in the direction of increasing ξ and station numbers. This positive direction is shown by directional arrows in Figure 2-7. Following a similar procedure as described above, fictitious discontinuities may be introduced at points where abrupt variation of load occur or where change in finite difference grid increment is desired.

The existence of a discontinuity junction at the endpoint of a region is specified by the end condition indicator BCITP (or BCIBM). For a discontinuity point, the indication values BCITP (or BCIBM) can be set equal to zero or >10. The printout for a discontinuity junction is given by the value 1×10^{10}.

To illustrate the use of end condition indicators and sequence of data input, the following table has been prepared for sample problem shown in Figure 2-7:

Table 2.1

Region	Boundary at i = 1 (BCITP)	Boundary at i = N (BCIBM)	GPSI	GECX
I	1	0	0	E_{cc}
II	0	0	20°	0
III	0	0	0	0
IV	0	0	0	0
V	0	3	0	0

2.10.2 Branch Junction

A branch point occurs when one region of a mathematical model is joined to two or three regions of the same mathematical model. The program will consider up to four shell regions or branches meeting at a common junction point. In the analysis of branched shells, a precise order must be followed in the inputting of data information. This order can best be exemplified by a typical branched configuration illustrated in Figure 2-2 on page 46. The numbers on each branch identify the regions or branches and indicate the sequence of data input for the regions comprising the multishell configuration. All required data for a particular region must be input before the next regional information is considered. The regions I-III are referred to as starting branches, the last regions are characterized by the fact that the last or N-th station in that region occurs at the common junction point. A closing branch has its first station (i = 1) at the branch point. The starting and closing branches must be selected in consistent form with the numerical solution procedure (Figure 2-2). The existence of a branch junction occurring at the endpoints of a region is designated by use of the end condition indicator BCITP (BCIBM) set equal to 10.

The program does not automatically handle eccentricities in reference surfaces occurring at branch point as was done at a discontinuity junction. However, since line moments can be applied at a junction, it is possible to account for the unbalance moment occurring at a branch point due to eccentricities in an approximate manner. This is accomplished by running a multibranch shell case (without eccentricity effects included) and calculating by hand the unbalance moment due to the couple generated by the in-plane membrane forces N_ξ ([illegible] Q_ξ contribution) in each region being displaced from each other. Applying the calculated unbalance moment as an externally applied line moment at the junction and rerunning the same case in the program will yield a corrected solution. This trial-and-error process can be repeated until the resulting error is as small as desired. Use of free body diagrams are helpful in setting up this model.

The procedure for setting up a branched configuration in the program can be illustrated by consideration of the example shown in Figure 2-2. In Figure 2-2, the first junction is a discontinuity point with ② and ③ being branched points. The arrows on the diagram indicate directions of increasing ξ or increasing station number for the respective regions. Regions II and III would be starting branches and IV the closing branch associated with junction ②; similarly, IV and V starting and VI closing branches characterizing junction ③. The sequence of input of data with appropriate end and discontinuity conditions can best be illustrated by Table 2-2.

Table 2.2

Region	BCITP	BCIBM	GPSI	GECX
I	9	0	0	0
II	0	10	315°	Not possible
III	3	10	0	Not possible
IV	10	10	0	Not possible
V	1	10	60°	Not possible
VI	10	9	0	Not possible

2.10.3 Discontinuity Loads

The effects of externally applied line loads and moments on a shell response can be determined using the program. The concentrated line load coded PD and moment MD are applied at junction points on the mathematical model. If no geometrical discontinuity exists, a fictitious discontinuity is introduced to incorporate the line load and moment. The program will permit a maximum of 11 Fourier components of PD and MD to be applied to the program. The value of PSI0 (in degrees) is the measured angle between the concentrated load direction and the normal to the closing branch at the common branch point. The positive magnitude of PD ($\bar{P}_D$) and MD ($\bar{M}_D$) is shown in Figure 2-8. For a branched configuration, the load and moment value occurring at a junction can be entered with the regional data of any (one only) of the starting branches; for example, the information could be supplied with data for either of regions I, II, or III. At a discontinuity point, the discontinuity loads would, of course, be supplied with the region preceding the junction point.

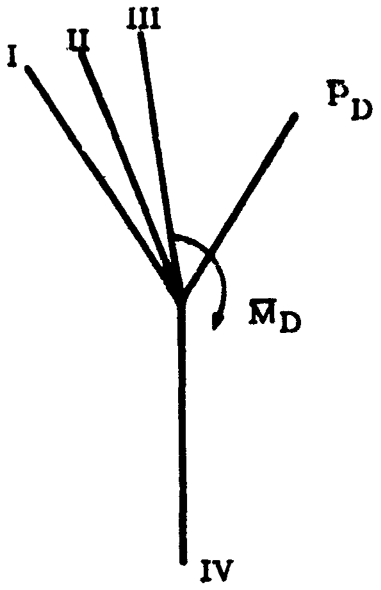


Figure 2-8

2.11 PRESSURE LOADS (PILD, PFETB, PTHTB, PNTB)

The values of surface pressure acting on a region are supplied at each station of the region. The sign convention for positive and negative values of pressure is shown in Figure 1.2d in its simplified form, internal pressure has a positive value and external pressure a negative value. The normal q and tangential loads q_ξ are assumed to be symmetrical about $\theta = 0$ and antisymmetrical for circumferential load q_θ. (See Section 1.7.)

To reduce the amount of data load information input into the program and to simplify the handling of unsymmetric loads, a pressure load indicator has been introduced. This indicator has the coded value PILD and permits different input format for various types of load information. The dimensional arrays PFETB, PTHTB, PNTB are used for inputting tangential, circumferential, and normal loads, respectively. These arrays, referred to as load tables, are dimensional for 200 information bits. The detailed procedure or table setup is given in Section 3.4.7, page 90.

When loads (or more specifically Fourier coefficients of load) are constant over the region, i.e., do not vary in the meridional coordinate, the PILD indicator is set equal to one. In this case, only one value of pressure load data is required for each Fourier harmonic (ENF) in each load table. For the case of unsymmetric loads that vary meridionally, the

Fourier components of load can be inputted at selected stations along the meridian. The program will automatically compute values at intermediate stations using the COPIMA curve-fit routine. (See Section 3.7.) PILD is set equal to two when using this option. Arbitrary unsymmetric loads can be described without prior knowledge of the Fourier coefficients of load distribution by using PILD option three. Discrete values of load are inputted in appropriate load tables at specific meridional and circumferential locations. A linear interpolation routine yields necessary values at intermediate locations, and the program automatically determines Fourier coefficients of loads using the Fourier-Euler inversion formula. The inversion integral is evaluated numerically with coded value ENTH indicating number of finite sums taken. It is recommended that the maximum number 91 be used for this value for general cases.

All pressure load data are inputted in dimensional form (i.e., in units of P/L^2) and the program automatically performs appropriate operations to make coefficients nondimensional (Section 1.7).

2.12 TEMPERATURE DISTRIBUTIONS (TBOT, TTOP, TITP, TIBT)

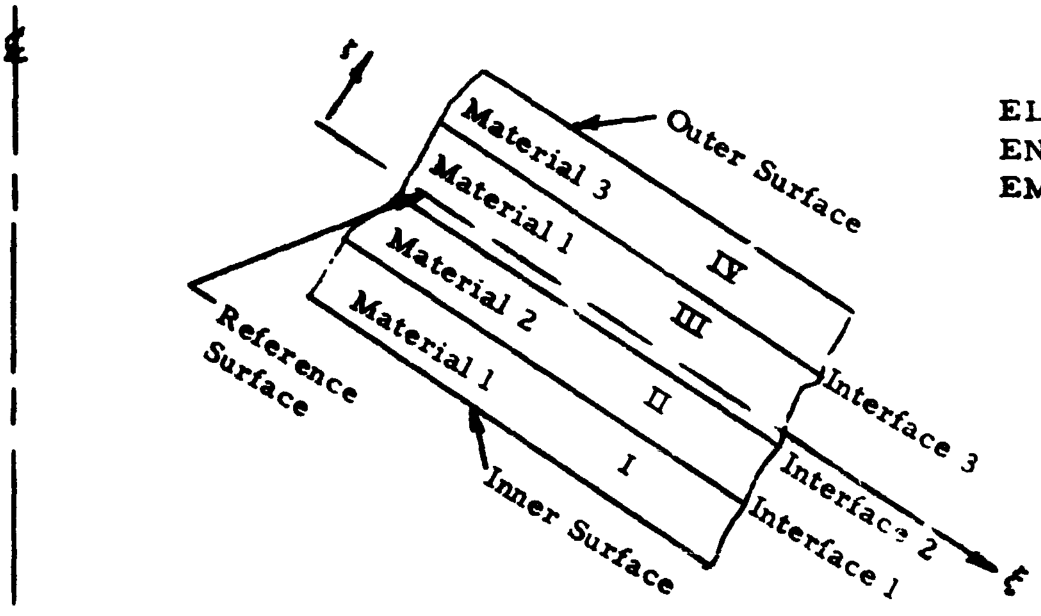
The temperature of the outer surface, each interface (multilayer shells), and inner surface must be supplied at each station of each region. The temperature data of inner and outer surfaces are inputted in a similar manner to pressure loads (see Section 3.4.7). Temperature indicators coded TIBT and TITP for inner and outer surfaces, respectively, are utilized with TBOT and TTOP representing table arrays for inner and outer surface temperature values.

Temperature distributions across the shell thickness are usually derived from solution of the heat transfer problem. The program handles only shell structural problems and does not make any heat transfer calculations. However, it does use the given temperature distribution to calculate stresses and deflections due to thermal influences in the shell. Since the temperature must be supplied at each face, there will be one more temperature value at each station than there are layers in the region. The outer and inner surface temperatures are supplied using procedures described above. The internal interface temperatures are supplied using a temperature gradient table for inputting interface temperatures at discrete meridional stations. An interface defines the surface between two shell layers (Section 2.13). The gradient value at each interface is prescribed as a percentage of the total differential between top and bottom surface temperatures. The number of gradient stations considered per region is coded ENOGR (10 maximum), with GSTA being station values at which gradients are supplied. The gradients are supplied at internal interfaces and GSTA stations counting from first interface beyond the inner surface to the last interface before the outer surface of the shell.

The temperature input data is not curve-fitted directly; instead, the program calculates the thermal load ENT and moment EMT at data input stations and curve-fits using CODIMA to give intermediate station values.

2.13 MULTILAYER SHELLS (ELAY, ENMAT, EMAT)

The computer program permits the analysis of multilayer shell configurations. Laminated shell sections having as many as six intimately bonded layers can be analyzed. The value assigned to the variable ELAY is the number of layers in the region. For identification, the layers are numbered consecutively starting from the inner surface. (See Section 2.4.) A region may consist of various layers of different materials each material having different elastic properties. A region of one material may be assumed to be divided into imaginary layers for purposes of determining stress internal to the outside and inside surfaces of the region or handling nonlinear temperature distributions across the thickness. The code value ENMAT indicates the number of different materials considered, for the problem with three being the maximum. The material layer indicator EMAT describes the material for each layer. The material used in a layer are numbered in sequence starting from inner layer and proceeding to outer layer. There are six possible values in the EMAT data locations, i.e., one for each layer. As an example, let us consider the four-layer shell section shown in Figure 2-9. The layer identification is given in Roman numerals. The sequence of data for EMAT, for example, would be shown 1, 2, 1, 3, i.e., material 1 in first and third layers, material 2 in second layer, third material in fourth layer.



ELAY = 4
ENMAT = 3
EMAT = 1, 2, 1, 3

Figure 2-9. Layer Shell

2.14 MATERIAL PROPERTIES (POIS, ENE1, TMPE1, YM1, ENA1, TMPA1, ALF1, ENE2, etc.)

In general, the elastic properties for structural material depend on the temperature of the material. In the computer program, the material properties, modulus of elasticity (Young's modulus), and coefficient of thermal expansion are permitted to vary as a function of temperature in the material. The material properties versus temperature data are read into the program in the form of tables for each individual material. The variables ENE1 and ENA1 describe the number of values of Young's modulus and coefficient of thermal expansions, respectively, that will be used in the tables for the first material. The code value TMPE1 represents temperatures of which the YM1 (Young's modulus) values are given in the tables for the first material. TMPA1 are temperature values at which the ALF1 thermal expansion coefficients are given. In the second material, similar code instructions are given by ENE2, TMPE2, YM2, ENA2, TMPA2, ALF2 and so on for the third material.) With the temperature at the layer interfaces and surfaces known, the values of Young's modulus and coefficient of thermal expansion are determined for each material at each interface by CODIMA curve-fit of the material property tables. The material property variation through each layer is obtained by linear interpolation. The value of Poisson's ratio is assumed constant in each layer and defined in the regional input data as the quantity POIS (six data locations possible, one per layer). The inaccuracies introduced by assuming a constant value of Poisson's ratio for each layer in a region are small and this assumption greatly simplifies the equations of the program. The distribution of material properties must be known before the stiffness properties and thermal loads can be determined at each station on the shell.

2.15 STIFFNESS PROPERTIES (EIFH, ENOTH, THSTA, TH, D, EK)

The stiffness properties of the shell can be evaluated when the material properties and shell thicknesses are known. The stiffness parameters must be supplied at each station in the region. The procedure for input of material property data is given in Section 2.14. For multilayer shells, the program permits the input of shell layer thicknesses in array form and automatically curve-fits data to ascertain thicknesses at intermediate station points. For the case of constant thicknesses, setting the variable EIFH to +1 permits the use of a simplified data format. For variable thicknesses, EIFH is set to -1 to permit reading of layer thickness tables. The quantity ENOTH sets the number of thickness stations given with THSTA being the active station number at which thicknesses are supplied (20 maximum). The station number must be the same for all layers. The thicknesses are read in by the quantity TH in order of layers' thicknesses per station, e.g., for a five-layer shell, the thickness of each layer is read at a specific station before preceding to the next station. The order of layer input is consistent with description outlined in Section 2.13, i.e., first layer at inner surface preceding in order to the last layer on the outer surface.

The cross-sectional properties are evaluated from Equations 33 and 34. It is assumed that the material properties (and temperature distribution) varies linearly across each layer. Thus, all integrands will be broken up into a sum of linear functions of ξ and the integrals are evaluated numerically based on values of material properties at layer and branching surfaces. A similar procedure is used in evaluating the thermal load and moment expression described by Equations 35 and 36.

For the case of constant stiffness properties, the extensional (D) and flexural (EK) stiffness can be inputted directly into the program by use of the EX indicator discussed in Section 3.4.6.

2.16 INTERNAL SPRING SUPPORT (GSPRL, GUK, GVK, GWK, GEMK)

The program will allow the consideration of a support spring at any internal station in a region. The station location of the spring is specified by value GSPRL. The values of spring constants for the meridional, circumferential, transverse, and rotational spring supports are given by the symbols GUK, GVK, GWK, GEMK. This capability would aid in considering shell structures which have internal elastic restraints such as a circumferential ring or other type of elastic support conditions. The program with minor modifications can be extended to handle more internal support points if desired.

2.17 REFERENCE QUANTITIES (SIGO, EO, HO, AO)

SIGO, EO, HO, and AO represent reference stress, Young's modulus, thickness, and length quantities introduced in the analysis to provide non-dimensional Fourier coefficients of comparable magnitudes. (See Section 1.3.5.) It is usually most convenient to set the value of these quantities equal to one.

2.18 GRAPHICAL PLOTS (PIXI)

This is a program option permitting graphical plotting of results using the Stromberg Carlson automatic plotter. Nonzero values of PIXI will give plots. If no graphs desired set PIXI = 0.

2.19 SPECIAL INDICATORS (EX, PTHI, PFLAG, STRI)

There are several indicators in the program that yield certain features in the program that cannot be classified completely under the paragraph description presented previously.

The program will permit the stacking of problems so that more than one problem can be run with a job submittal. Theoretically, any number of problems can be stacked. The indicator PTHI is used to eliminate the repetition of data when similar problems are used. A PTHI value equal to zero indicates a normal program path. Positive PTHI values permit skipping of the geometry subroutine with the shell geometry remaining identical to the preceding case. A negative value of PTHI retains all shell properties from preceding case but permits variation of surface loads.

The PFLAG indicator permits the printing of all input data when the value is set to nonzero. In addition, a negative PFLAG will yield print information of a diagnostic type.

The quantity STRI indicates the layer at which a second value of stress across the thickness is desired. The value of stress at the inner surface of the specified layer is printed. Zero value of STRI automatically gives the stress at the outer surface of the shell.

The EX indicator is an option formulated to simplify data when running cases with constant loads and section properties are considered. This option is invaluable in running simple check cases. The details on this use of the EX symbol is given in Section 3.4.6.

2.20 CURVE FITTING

As discussed in previous sections, the shell parameters and loads are curve-fitted using the controlled deviation interpolation method concept (CODIMA). CODIMA basically involves fitting a second-degree polynomial through three successive points in the data field. Thus, the curve passes exactly through the supplied input points. The detailed characteristics of CODIMA are outlined in Section 3.7.3 and will not be repeated here. CODIMA was selected because it offers an accurate, efficient, and reliable technique for fitting data. As contrasted to "least square" techniques, it does not exhibit ill behavior in treating even the most complex of functions. Of most importance, CODIMA fits automatically and does not require additional input construction to be supplied by the user.

2.21 GENERAL COMMENTS

A number of difficulties may arise as a result not of errors in the program or its writeup but of certain subtleties connected with shell theory and the construction of the program. It would be foolhardy to attempt to outline all these difficulties and subtleties here. However, it would perhaps be worthwhile to give some simple tips to serve as a reminder in use of the program.

1. The user should always check the output data from the program to see if it corresponds to input entered. In using curve-fit techniques (CODIMA) it may be desirable to input more data than absolutely necessary to increase the accuracy of representative results.

2. Some difficulty may be encountered in selecting a mathematical model particularly when treating branching configurations; for example, some ambiguity is discovered in the definition of thickness for each shell region in the junction region. Careful study of Section 2.10.3 with the exercise of good engineering judgment should permit the selection of an adequate engineering model.

3. The user should be reminded that shell theory is two-dimensional and input parameters and results should be interpreted accordingly. The results, of course, will only be as good as the mathematical model selected.

4. The discrete point option (GMI = 3.0) should be used only when the shell geometry cannot be described by the other geometry options. If this option is used, it is strongly recommended that the capability for input of radius of curvature information be utilized. A dense population of input data must be supplied when using this option in order to guarantee an accurate geometrical representation.

5. For multiregion configurations, extreme care must be exercised to ensure that the geometrical location of a junction point is matched between regions. In addition, best results are obtained if the finite difference intervals are selected to be approximately equal on each region.

6. Some difficulty may be encountered in treating problems having apex-apex or free-free boundary conditions. Rigid body type motion may occur when data are not input precisely. For some problems where some "drift" occurs, it may be possible to supply a nonforce-inducing spring to the shell in order to obtain a zero reference point for displacements.

III. DETAILED USE OF THE PROGRAM

3.1 INTRODUCTION

The Shell of Revolution Computer Program is written almost entirely in FORTRAN IV and makes use of the overlay feature of that language. The exception is found in the utility subroutine CRTG, described in Section 3.7.5.

The program has been checked out in NAASYS, the NAA adaption of the IBM 7090/7094 IBSYS/IBJOB system and uses the NAASYS library routines shown in the load map, pages 67 to 73, inclusive, this section.

The NAASYS input tape is 'UNIT05,' the output tape is 'UNIT06,' and the system CRT file is 'UNIT16.' In addition to these files, the program uses 3, 4, 7, 8, 9, 10, 11, 12, and 13 as scratch tapes or for overlay storage during execution. NAASYS itself, is stored on 'UNIT01.'

The program is made up of an executive program and eight links, five of which are called by the executive program, and the other three by the DATLNK subroutine. The name of the main program in each link and a description of its use follows.

Link No.	Name	Purpose
0	EXECUTIVE	Reads the general data, DA, and controls the flow of execution of the other links.
1	DATLNK	Acts as a subexecutive program to control GEOM, DATLDS, and DATLYR, the subroutines that set up regional data. Also reads special data, SDA. Prints Section and Material Properties and Loads.
2	GEOM	Reads geometry parameters/region. Calculates DEL, R, X, WFE, WTH, GAMA, and RHO. (See program nomenclature, Section 3.10.) Prints all geometry input and calculated values.

Link No.	Name	Purpose
3	DATLDS	Reads pressure loads and temperatures for the inner and outer faces/region, DLD. Makes pressure dimensionless and, depending on indicator, sends a constant, curve-fits or Fourier sums for values at each meridional station. Sets up temperatures at 20 stations for use in DATLYR. Some data prints on indicator.
4	DATLYR	Reads section and material properties data, DAL/region. Sets up D, EK, ENT, EMT, EI, T, ALF at all meridional stations. (The first four mentioned are made dimensionless.) Some data prints on indicator.
5	PANDX	Forms the P and X matrices of Equations 74 and 75 (Section 1.13) needed in the solution of the difference equations.
6	INTLD	Uses the P and X matrices from link 5 to form the solution matrix, z. (Equations 76 and 77, Section 1.13) Computes the current Fourier component for the bending moments, transverse shear forces, membrane forces, and stresses.
7	SUMS	Performs the Fourier summing for unsymmetrical loading conditions. Prints results. Sets up tapes and indicators for next Fourier component.
8	PIX	Plots shell geometry, displacements and other results from link 6/region. (Results are printed for all THETA values but are plotted for just the first THETA.)

3.2 DECK SET-UP

In Figure 3-1 we have shown the set-up of the column binary program deck, with the necessary control cards for each link.

The $IBJOB, $ORIGIN, and $DATA cards are single control cards. The circled numbers found on the first two control cards mentioned indicate the order in which they, plus the associated decks of that link, should be

```
            IBLDR                                          09/16/86          PAGE  69

                  OVERLAY ORIGIN CARDS AND ASSIGNED LINK NUMBERS

$ORIGIN        LNK                        IS LINK   1, PARENT LINK IS   0
$ORIGIN        LNKA                       IS LINK   2, PARENT LINK IS   1
$ORIGIN        LNKA                       IS LINK   3, PARENT LINK IS   1
$ORIGIN        LNKA,REW                   IS LINK   4, PARENT LINK IS   1
$ORIGIN        LNK                        IS LINK   5, PARENT LINK IS   0
$ORIGIN        LNK                        IS LINK   6, PARENT LINK IS   0
$ORIGIN        LNK                        IS LINK   7, PARENT LINK IS   0
$ORIGIN        LNK,REW                    IS LINK   8, PARENT LINK IS   0
```

Shows the relation between
the overlay links.

Overlay Origin Cards and Assigned
Link Numbers

```
        IBLDR                                                    09/14/66          PAGE  70

                  * MEMORY MAP *

SYSTEM                                    00000 THRU  03765
FILE BLOCK ORIGIN                         03766
FILES         1.      UNIT01
              2.      UNIT02
              3.      UNIT03
              4.      UNIT04
              5.      UNIT05
              6.      UNIT06
              7.      UNIT07
              8.      UNIT08
              9.      UNIT09
             10.      UNIT10
             11.      UNIT11
             12.      UNIT12
             13.      UNIT13
             14.      UNIT14
             15.      UNIT15
             16.      UNIT16
FILE LIST ORIGIN                          04266
PRE-EXECUTION INITIALIZATION              04326
CALL ON OBJECT PROGRAM                    04373
OBJECT PROGRAM                            04400 THRU  51121

LINK  DECK  ORIGIN      CONTROL SECTIONS  (/NAME/=NON 0 LENGTH, (LOC)=DELETED, *=NOT REFERENCED)

  0  148BR   04400     ///      /(67372)    EVEN     04401      ......  05177 *
     MAD     05213      MAD     (05213)
     MSU     05323      MSU     (05323)
     MMY     05433      MMY     (05433)
     .LINK   05601     /.LDT   / 05601     /.LPECT/ 05612      /.LVFC / 05632
     .LXCON  05652      .LXSTR   05652      .LXSTP   05657      .LXOUT   05754      .LXERR   05766
                        IBEXIT   05772 *    .LXRTN   05772      .LXCAL   05776 *    .IOCLS   06164 *
                        .LXARG   06305      .LO      06324     /TDUMPQ/ 06326 *    .CLSE    06332
                        .LFBL    06333 *    .LUNB    06334      .DFOUT   06335      CTES..   06337
                        SC.SWT   06340     /SMR1.V/ 06341      .OPNFQ   06360      .CLSE)   06361
```

NANSYS reserves buffer areas
for all tape units if any read
or write statements contain
a variable unit name.

Map of Core Storage

```
    IBLDR                                                            06/16/65          PAGE   71

                         .WRTFQ   06362     .REDFQ   06363     CNTL..   06364
.IODEF   06367           .DEFIN   06367     .ATTAC   06373 *   .CLOSF   06375     .OPEN    06377
                         .READ    06401     .WRITE   06403     .BSP     06413     .READP   06423 *
                         .RELES   06425 *   .LAREA   06436 *   .LFBLK   06454     .LTSX    06457 *
                         .AREA1   06471     .LUNBL   06477 *   .ENTRY   06503     .GOA     06536
                         .GO      06542     .DERR    06556     .NOPXI   06562     .COMXI   06564
                         .EX34    06606     ..FPUN   06613     ..PLOT   06613
.IOCSF   06614
.LOVRY   12136           .LOVRY  (12136)    .LDT    (05601)    .LRECT  (05612)    .LVEC   (05532)
.LXSL    12710           .LXSEL   12710     .LXSCL   12711     .LXTST   12714 *   .LXOVL   12762 *
                         .LXRCT   12773 *   .LXIND   13132     .LXDIS   13140     .LXFLG   13141
                         .LTCH    13146
.FPTRP   13166           .FFPT.   13166 *   .FPOUT   13322     .FPARG   13332     /.COUNT/ 13334 *
                         OVFLOW   13405 *
.ERAS.   13412           E.1      13412     E.2      13413     E.3      13414     E.4      13415
.XCC.    13416           CC.1     13416     CC.2     13417     CC.3     13420     CC.4     13421
XIT      13422           EXIT     13422     .EXIT.   13422
FXEM     13423           .FXEM.   13423     .FXOUT   13756     .FXARG   13764     /.OPTW./ 14040
OPXP.Q   14052           RDOPXQ   14052 *   OPEXQ    14054
FOUT     14120           .FOUT.   14120
FCNV     14461           .FCON.   14461     /HWDSQ / 14511 *   /NOHSHQ/ 14513 *   .FCNV.   14515
                         .ENDFS   14534     .CNVSW   14536     .FDX1    14542     .FDX2    14543
                         .DBC     14545     .DBC10   14703     .DBC20   14731     .DDSW    14741
                         .DDFIX   14750     .FIXSW   14756     .DDBC    15033     .DDRS1   15276
                         .DDRS2   15300 *   .D1      15303     .D2      15305     .FERR2   15372 *
                         .ANPT    15426     .ONPT    15443     .LNTP    15526     .AOUT    15575
                         .DFLT    15614     .FLT     15751     .DEXPN   16042     .FXD     16043
                         .HOUT    16174     .INTG    16245     .LOUT    16365     .OOUT    16406
                         .XCF     16440     .TEST    17146     .KOUNT   17151     .LIST    17154
                         .DONE    17165     .OUTBF   17232     EVEN     17231     .BUF     17262
                         .QSTO    17263     .WIDTH   17264     .GAIN    17265     .GAIN1   17266
                         .FBDBF   17276     EVEN     17307     .DDDFL   17323     .DDFLG   17324
                         .MOD     17325     .PEX     17326     .FEXP    17327     .DIG     17330
FIOB     17346           .FIOB.   17346     .FCNT    17451     .FBLT.   17547     .FBDT.   17567
                         .FRLR.   17613     .FRLR.  (17613)    .FWLR.   1765      .FDLR.  (17557)
                         .FBIBF   17717     .FRITE   20011
FIOS     20017           .FIOS.   20017     .FSFL.   20206     .FILR.   20212 *   .FRTB.   20221
```

Map of Core Storage (Cont)

```
                 .FFTU.  20226     .FILL.  20244     .FCLS   20261 *   .FOPN   20265 *
                 REOF    20271 *   REOF.Q  20300 *   .TOUT.  20434     .REFD   20444 *
                 .BIN    20445 *   .FCT    20446     .FCKSZ  20450     SEOF.Q  20471 *
FIOH    20547    .FIOH.  20547     .FFIL.  21334     .FRTN.  21361
FWRD    21557    .FWRD.  21557
FWRB    21603    .FWRB.  21603
FRDD    21627    .FRDD.  21627
FRDB    21655    .FRDB.  21655
UN01    21701    .UN01.  21701
UN02    21702    .UN02.  21702
UN03    21703    .UN03.  21703
UN04    21704    .UN04.  21704
UN05    21705    .UN05.  21705
UN06    21706    .UN06.  21706     .BUFSZ  21707
UN07    21712    .UN07.  21712
UN08    21713    .UN08.  21713
UN09    21714    .UN09.  21714
UN10    21715    .UN10.  21715
UN11    21716    .UN11.  21716
UN12    21717    .UN12.  21717
UN13    21720    .UN13.  21720
UN14    21721    .UN14.  21721
UN15    21722    .UN15.  21722
UN16    21723    .UN16.  21723
FLOG    21724    ALOG10  21724     ALOG    21725
FSCD    22130    COSD    22130     SIND    22132
FSCN    22161    COS     22161     SIN     22162
FSQR    22355    SQRT    22355
FXP2    22430    .XP2.   22430
FBST    22546    .FBST.  22546
FRWT    23003    .FRWT.  23003
FSLDI   23122    .FSLI.  23140     .FSDI.  23146 *
FSLBI   23157    .FBLI.  23175     .FBDI.  23203 *
FSLI    23215    .SLI.   23215     .SLI1.  23222     .SDI.   23230     .SDI1.  23236
FSLDO   23251    .FSLO.  23267     .FSDO.  23275 *
FSLBO   23306    .FBLO.  23324     .FBDO.  23332 *
FSLO    23344    .SLO.   23344     .SLO2.  23352     .SDO.   23357     .SDO2.  23365
```

Map of Core Storage (Cont)

```
        IKLDF                                                         03/16/86            PAGE  73

DECPD    23400      DECPD  (23400)
SMR2.Q   23516      /..PLOT/(06613)    /.PLOT./(23516)    /END.ID/(23517)    /.PLOT./ 23516
                    /END.ID/ 23517     /XXXX../ 23526      EVEN     23525    /YYYY../ 23527
                    /AX..   / 23530    /AY..   / 23531 *  /BX..   / 23532    /BY..   / 23533 *
                    /XHI.. / 23534     /YHI.. / 23535     /XLO.. / 23536     /YLO.. / 23537
                    /ML..   / 23540    /MR..   / 23541 *  /MB..   / 23542    /MT..   / 23543 *
                    /WIDF../ 23544     /HIGH../ 23545 *   /Z..PTA/ 23550     /.XXSYY/ 23551
                    /....YY/ 23552     /.XX.YY/ 23553     /...S../ 23554 *   /HOLD../ 23555
                    /YTOP../ 23556     /YRFG../ 23557     /CTPE../ 23560     /CAMV../ 23561
                    /IDOK../ 23562     /ID.CUT/ 23563     /CUT.. / 23564     /LEGN.D/ 23565
                    /STOP../ 23573     /BUTT../ 23574     /XPND../ 23575     /CHOP../ 23576
                    /SMR2.V/ 23577 *
SMR3.Q   23745       SCCU..   23745     BUMP..   23765
BNBCDC   23770       BIN .D   23770 *   BNBCDV   23770
BRITEV   24210       BRITEV (24210)     FAINTV   24212 *
ERMRKV   24242       ERMRKV (24242)
ERRLNV   24256       EVEN     24257     ERRLNV (24256)
ERRNLV   24432       EVEN     24433     ERRNLV (24432)
GRIDIV   24617       GRIDIV (24617)
HOLDIV   25547       HOLDIV (25547)     HOLDOV   25552
LABLV    25555       LABLV  (25555)
LINEV    26060       LINEV  (26060)
LINRV    26220       EVEN     26221     LINRV  (26220)
NONLNV   27053       NONLNV (27053)
PLOT..   27466       PLOT.. (27466)     CAMRAV   27517 *   FRAMEV   27560     RESETV   27562 *
                     CFF      27562 *   .IDFRM   27660
PLOTV    30220       PLOTV  (30220)
PRINTV   30237       PRINTV (30237)
SETCIV   30347       SETCIV (30347)     SETCOV   30353
SETMIV   30357       SETMIV (30357)     SETMOV   30366
SMXYV    30375       SMXYV  (30375)     MSXYV    30402
STOPTV   30407       STOPTV (30407)
VAXV     30414       VXAXV    30414     VYAXV    30417
XMODQ    30464       XMODV    30464     YMODV    30464
XPANDV   30465       XPANDV (30465)     RXPNDV   30473
XSCALQ   30476       XSCALV   30507     YSCALV   30513     NXV      30626     NYV      30632
                     IXV      30671     IYV      30673     SCERRV   30676 *   SERSAV   30703 *
```

Map of Core Storage (Cont.)

```
                   SFRREV   30710 *   UXV      30717 *   UYV      30723 *   SCLSAV   30734
                   RFSCLV   30746 *
   FVIO     31013  .FVIO.   31013
   LOCSAV   31127  LOCSAV  (31127)    LOCSTV   31137
   NOFRV    31156  NOFRV   (31156)
   SCOUTQ   31165  SCOUTV   31165     SCTV.2   31224
   //       67372

1  CLNK     31322  ///     /(67372)   EVEN     31323     DATLNK   32437
   CF3P     32455  CODIMA   33470

2  GMTRY    33616  ///     /(67372)   EVEN     33617     GFOM     44266

   CLDS     33616  ///     /(67372)   EVEN     33617     DATLDS   45036
   CNTP     45067  DINTRP   45353
   ENTP     45412  EVEN     45413     ENTERP   45601

4  CLYR     33616  ///     /(67372)   EVEN     33617     DATLYR   44132
   STN      44160  EVEN     44161     STCOMB   44306

5  PXMAT    31322  ///     /(67372)   EVEN     31323     PANDX    47344
   PXDO     47373  ///     /(67372)   DOLP     50161     DDO      50235     DOA      50254
                   DOB      50300     DO1      50324     DO2      50327     DO3      50332
                   DO4      50342     DO5      50345
   INV      50350  EVEN     50351     INV     (50350)

6  INLDS    31322  ///     /(67372)   EVEN     31323     INTLD    50414

7  FSUMS    31322  ///     /(67372)   EVEN     31323     SUMS     44566

8  CRT      31322  ///     /(67372)   EVEN     31323     PIX      37631
   DATAG    37650  /COMMG / 37650     EVEN     37647    /ERRORG/  37662    /HARG   / 37654
                   EVEN     37663    /HOLDG /  37666    /INTG   / 37672    /LIMITG/  37674
                   EVEN     37673    /MESHG /  37700    /TABG   / 37702     EVEN     37701
   CPTG     37715  LINEG    37715     POINTG   37720 *   FTCG     37721 *   RESETS   40147 *
   CRTMOD   40166  /LINCRT/ 40166 *  /L.NCRT/  40166    /LCGCRT/  40167 *  /L.GCRT/  40167
                   /L.NCRT/(40166)   /DXDYV /(42070)    /ERRLNV/(24256)    /LINRV  /(26220)
```

Map of Core Storage (Cont)

```
          IBLDR                                                                        08/16/86                 PAGE  75

                        /L.GCRT/(40167)    /LOGDXV/(42142)    /ERRNLV/(24432)    /MONLNV/(27053)
                        /XMODV /(30464)    /YMODV /(30464)
      SCALE*   40170    /COMMG /(37650)    /ERRORG/(37662)    /HOLDG /(37656)    /LIMITS/(37674)
                         EVEN     40171     SCALEG  40335
      PLOTG*   40347    /COMMG /(37650)    /ERRORG/(37662)    /INTG  /(37672)     PLOTS   40536
      GRIDG*   40552    /DXDYQ / 40554      EVEN     40553    /HMRG  /(37664)    /LIMITS/(37674)
                        /MFSHG /(37700)    /TABG  /(37702)     GRIDG   41216
      SCMRG    41234
      DXDYV*   41251    /DXDYQ /(40554)     DXDYV    42070
      LOGDXV   42142    /DXDYQ /(40554)     EVEN     42143     LOGDXV (42142)
      ILINE*   42355     ILINE    42735
      CFFSC    42775

  I/O BUFFERS                       51122 THRU  67352

  UNUSED CORE                       67353 THRU  67371
  BEGIN EXECUTION     32                                    18-49-22
```

Map of Core Storage (Cont)

stacked. For example, the second level subroutines, GEOM, DATLDS, and DATLYR, will be found in the deck before the first-level subroutine, PANDX, because they are executed in this order.

It is imperative that the utility subroutines be kept with each link as shown. The matrix arithmetic subroutines, MAD, MSU, and MMY, are required by PANDX and INTLD, but since only one first-level subroutine may occupy core at a given time, they are entered with the EXECUTIVE link so that they may be shared by both.

Additional control cards preceding the $IBJOB card are likely to vary somewhat with the installation. An IBM systems handbook should be consulted.

```
9 184705 0 $JOB   IBJOB      C13504410956  32  192025880412 2FURUIKE     8305

9 184705 0 $IBJOB
9 184802 0 $*
9 185033 0 $IBSYS
```

Additional control cards used at S&ID

3.3 PROGRAM FLOW DESCRIPTION

An overall flow diagram of the paths between the EXECUTIVE program and the first-level subroutines, and between the subroutine DATLNK and its second-level subroutines, is included in Figure 3-2.

A detailed flow diagram of each of these major control type routines, i.e., EXECUTIVE and DATLNK, is also included in Figures 3-3 and 3-4, respectively.

Many comments cards have been included in the listings of the other subroutines to aid in understanding their flow. (See Appendix IIIA, pages 181 through 273.)

3.4 INPUT DATA FORMAT

3.4.1 Introduction

Two types of data are entered in the program: (1) general data that is read by the EXECUTIVE program and (2) regional data that is controlled by DATLNK. Depending on the values entered for the indicators PTHI (see DA data, Section 3.4.4) and EX (see SDA data, Section 3.4.6), the DATLNK subroutine will call or omit calling GEOM, DECRD(SDA), DATLDS, and

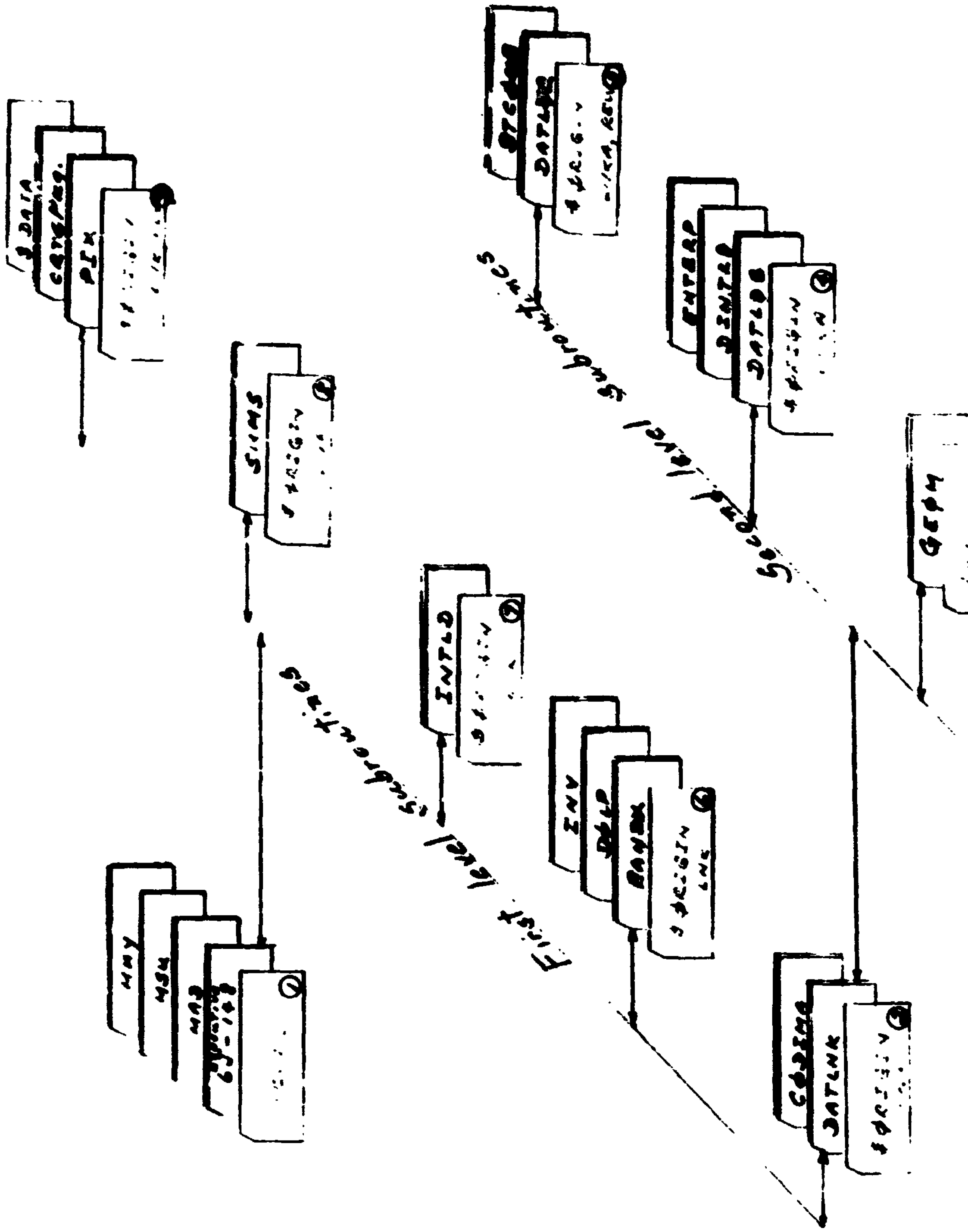


Figure 3.1 Setup for Deck 6J-148

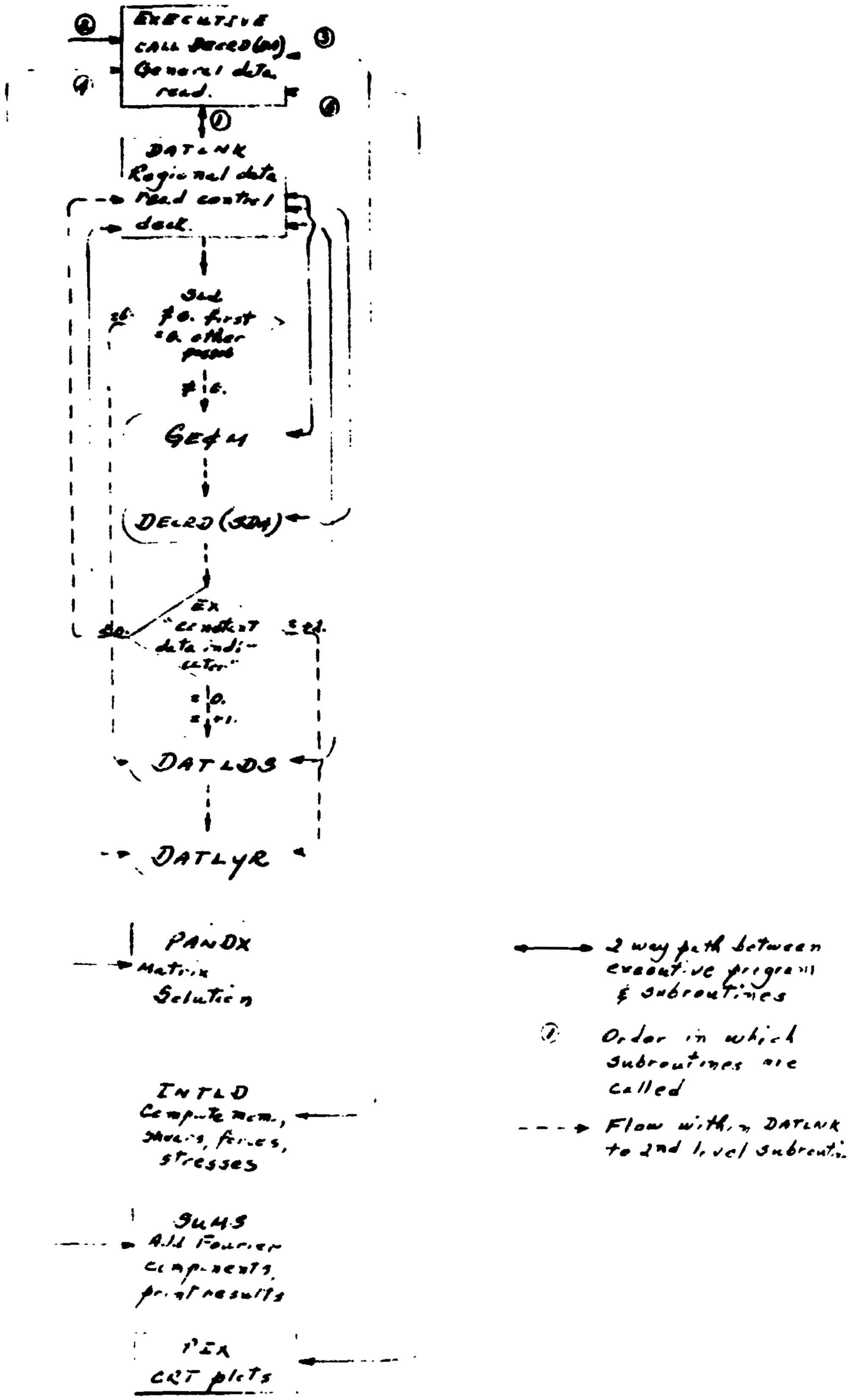


Figure 3.2. Program Flow

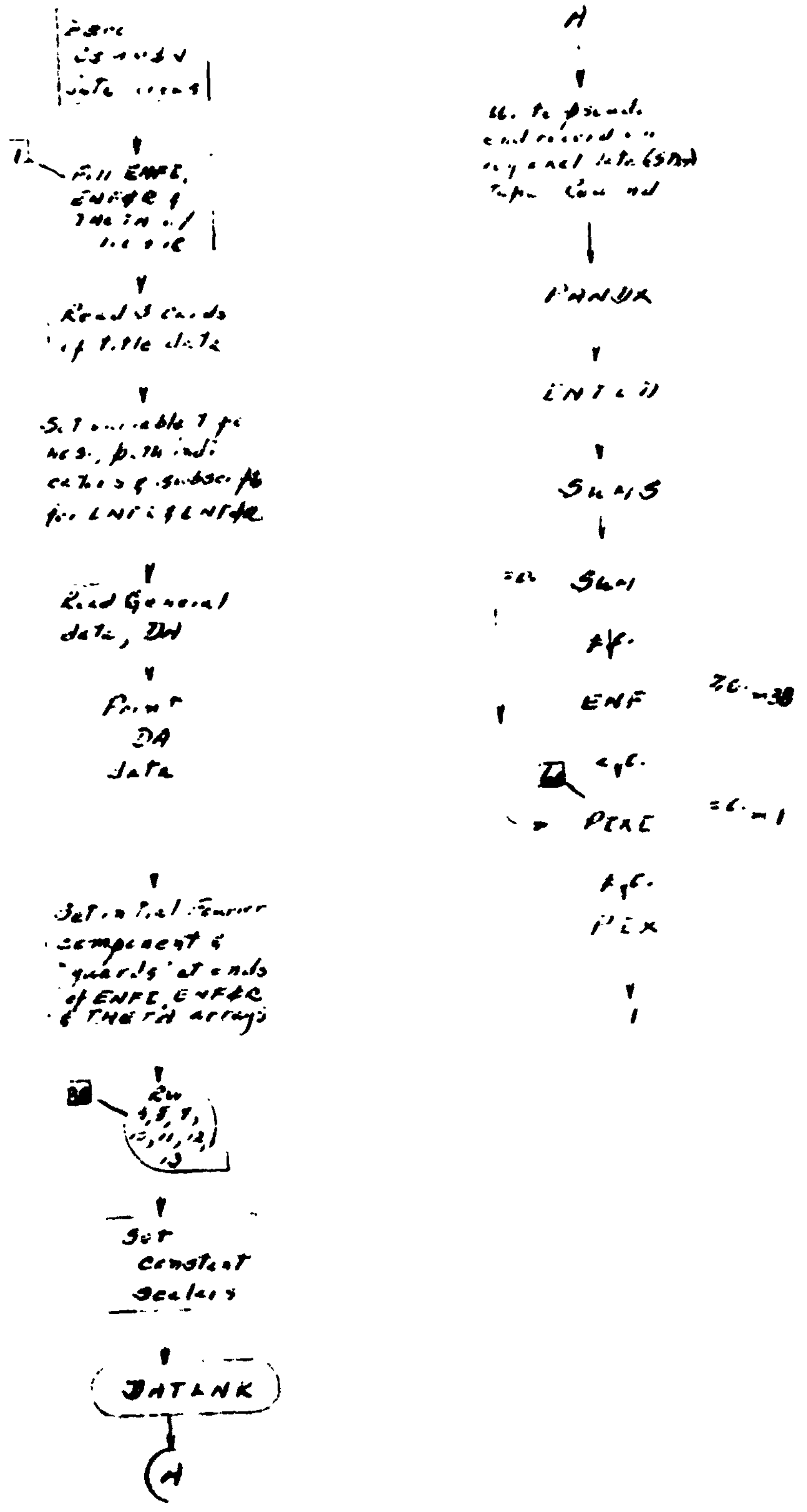


Figure 3.3. Executive Program

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR."

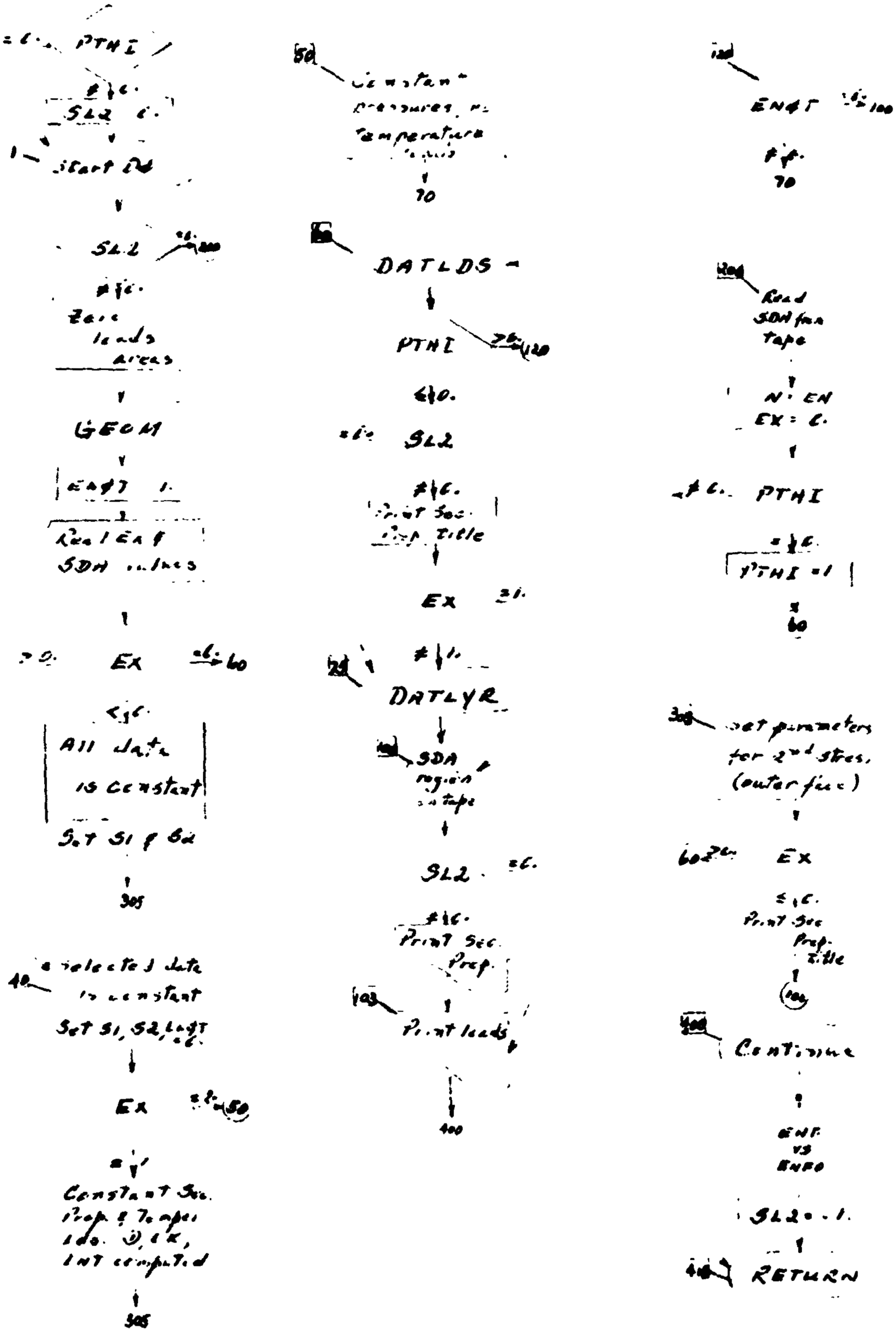


Figure 3.4. DATLNK - Regional Data Control Program

DATLYR. These latter four subroutines are cycled per region. A full explanation of the data for each routine, together with sample data sheets, is included in Sections 3.4.4 through 3.4.9.

Figure 3-5 shows the possible flow between the various data reading subroutines.

3.4.2 DECRD Subroutine

All data, with the exception of the three title cards, is read by means of the DECRD subroutine, available on the NAA library tape.

This routine provides the facility for reading a variable number of pieces of floating point data into specified elements of an array; these elements may be in either sequential or nonconsecutive locations. Only the information specified is actually read into storage.

16

4.6

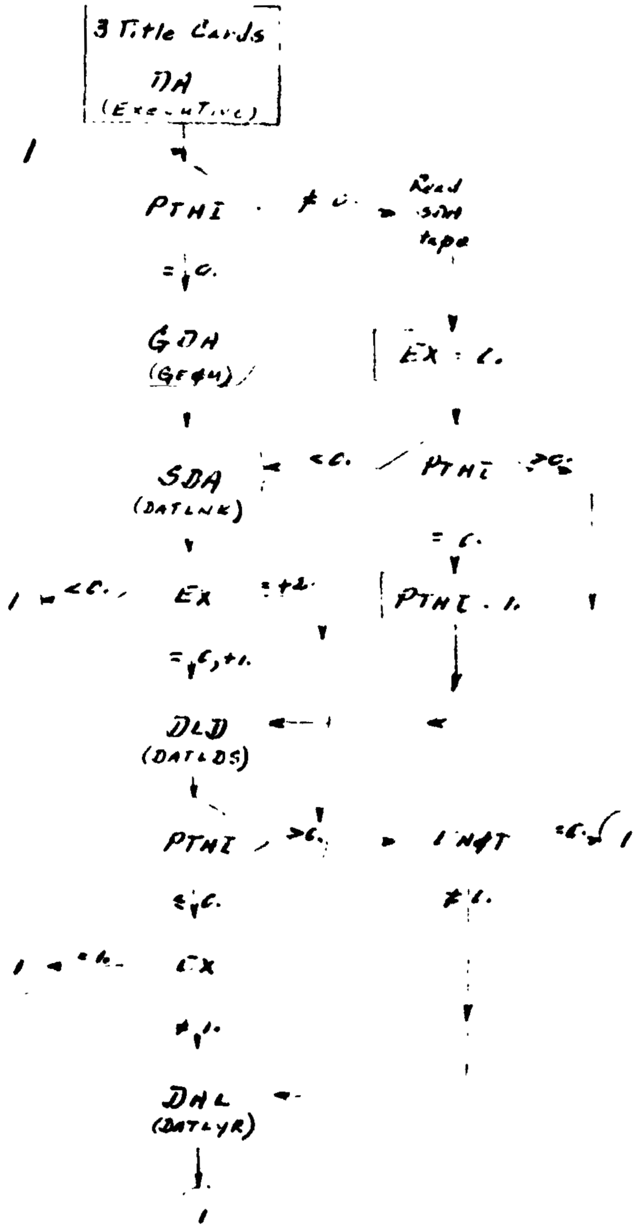
0.

1.   +17

3.3   -2   24

The fixed point number (index) in the first field on each card defines the position of the first piece of data on the card. If the index is 1, the first piece of data will be stored in the first location reserved for the array; if it is 16, the first word will be placed in the sixteenth position, etc. The remaining fields on each card contain information for the successive locations of the array. If one or more fields are left blank, no information is read into the locations corresponding to these fields; the information already in these locations is unaltered.

The sample data sheets shown in Section 3.6.3 have six fields of 12-card columns each and an identification field of eight columns for sorting purposes.



1 Start of region DØ loop. Cycles for EKK regions. See DA data, section 3.4.4

PTHI, path indicater See DA data, sec 3.4.4.

EX, constant data indicater See SDA data, section 3.4.6.

ENØT, no. of temperature stations When zero, no temperature loads This indicater is set by the program.

Figure 3.5. Flow Chart for Data Reading

a. The index must be written to the extreme right of the first field; it may not be zero or blank (no decimal point).

b. The programmer should keep in mind the way in which FORTRAN stores arrays having double or triple subscripts, e.g. A(1, 1), A(2, 1), A(3, 1), A(1, 2), A(2, 2), etc.

c. The floating point (REAL) data should be entered with a decimal point (anywhere in the field) and an exponent, when necessary, written to the extreme right of the field and preceded by a '+' or '-'.

d. Reading data is concluded by placing a negative sign in column 1 of the last card to be read.

e. Zero should always be entered as '0. '. A '-0. ' or '. 0' will be recognized as a blank.

ERROR indication: If the index is zero or blank, the comment "****BAD INDEX ON DECRD CARD-" will be printed, followed by a printout of the columns 1-80 of the defective card. The job will be terminated.

If the data for the array in the CALL statement have been completely read and no negative sign has been encountered in column 1 of last card read, data intended for subsequent CALL's will be read into the incorrect array. When there are no data cards to satisfy the appetite of a CALL DECRD statement, the job will terminate with an end of file tape 5 designation, as shown below.

```
TRACEBACK - CALLS IN REVERSE ORDER.

   CALLING               IFN OR            ABSOLUTE
   ROUTINE               LINE NO.          LOCATION

     FIOS                  333              20471

     FRDD                   13              21632

     14BBR                  17              04635

NAA USER MESSAGE    141

END OF FILE READING          UNIT05

EXECUTION ENDED.
```

If this occurs before all expected results have been printed, check the last card of each data block for the negative sign in column 1.

3.4.3 Data Deck Setup

Data decks should be stacked as follows:

1. Three cards (72 columns each) of title data
2. DA, general shell data. read by the EXECUTIVE program
3. GDA, geometry data, read by the GEOM subroutine
4. SDA, special data cases, read in DATLNK subroutine
5. DLD, loads data, read in DATLDS subroutine
6. DAL, section properties data, read in DATLYR

With the exception of the three title cards, each group of data listed above should have a minus sign in column 1 of the last card. Groups three through six are repeated for additional regions. Remember that some portions may be omitted due to the values of indicators EX or PTHI. (See flow chart, Figure 3-5, Section 3.4.1.)

3.4.4 Title Cards and Call DECRD (DA)

Three title cards form the first three cards of any data deck for each case. These cards are useful in identifying the run at a later date. They may include a brief problem description, the date of the run, a reference, etc.

These cards may not be omitted, but they may be blank, if desired. If the cards are forgotten, the error indication from DECRD will occur for a multiple case run, or the job will terminate with an end of file tape 5 designation (as explained in Section 3.4.2) provided the DA data for the case was three cards or less.

All input data must be dimensionally consistent. It should be noted that all nondimensionalization is done internal to the program; thus, all inputs must be supplied with appropriate dimensions (e.g., transverse load PN is input with dimensions P/L^2). In the instructions that follow, the input quantities in terms of nomenclature of Section I are listed in the description and comments.

DECRD Index	Name	Description and Comments
1	EKK	Number of regions (50 regions estimated limit)
2	AO	Reference length (a)
3	HO	Reference thickness (h_o)
4	EO	Reference Young's modulus (E_o)
5	SIGO	Reference stress (σ_o)
6	PIXI	CRT indicator. Plots curves when nonzero. Must be zero when SUM is negative.
7	PTHI	Path indicator First case = O, "normal" path Following cases: a. Negative - skip GEOM; geometry is the same as preceding case b. Positive - loads change only
8	SUM	Nonzero for multiple Fourier components a. Positive - results are summed, with prints given at ENFOR values b. Negative - discrete Fourier components printed each time. No CRT
9	ENFO	Initial Fourier component (n)
10	ENFI	Subsequent Fourier components (10 more)
21	ENFØR	Fourier component print values. Three prints are permitted. Two intermediate prints of the Fourier summing are possible for checking convergence. The last ENFOR given should be the same as the last ENFI
25	THETA	Circumferential angle θ (degrees), 10 maximum

ENFI, ENFOR, and THETA values must be read for each case. DA(1) through DA(9) are set to zero before reading the first case data but, for multiple case runs, they will retain their values unless changed by the programmer.

3.4.5 Call DECRD (GDA)

The GDA data array is zeroed each time before the above statement is executed. This means that all GDA data must be repeated for multiple-region or multiple-case runs.

DECRD Index	Name	Description and Comments
1	GMI	Geometry indicator = 1. cone-cylinder = 2. sphere-toroid = ±3. discrete points = 4. ellipse = 5. hyperbola = ±6. parabola
2	EN	Number of station points per region (150 maximum)
3	PFLAG	Print indicator. Nonzero prints all input data. A negative PFLAG prints additional information of a diagnostic type (see Section 3.5).
4	BCITP	Boundary condition indicator at first station i = 1 (top)
5	BCIBM	Boundary condition indicator at last station i at N (bottom) = 1. free (t_ξ, $\hat{t}_{\xi\theta}$, $\hat{f}_\xi$, m_ξ = 0) = 2. roller (t_ξ, u_θ, $\hat{w}$, m_ξ = 0) = 3. clamped, fixed (f_ξ, u_θ, u_θ, w = 0) = 4. simply supported, hinged (u_ξ, u_θ, w, m_ξ = 0) = 5. complete ($\hat{t}_\xi$, f_ξ, u_ξ, u_θ = 0) axisymmetric load problem only = 6. special boundary matrices read in. Must use 6 whenever nonzero values are prescribed at boundary values in EM5X or EMN5 matrices = 9. closed apex (e.g., apex of sphere, pole condition). Set one of the apex end conditions to -9 for apex-apex type boundaries. = 10. branch point (more than 2 regions joining) ** At a branching discontinuity only one region may have a top boundary indicator of 10 = 0, 1. E+10 discontinuity junction (two regions joining)

DECRD Index	Name	Description and Comments
6	GPSI	Discontinuity in slope at the end of the region (degrees) (See Figure 2.1 ②)
7	GECX	Eccentricity of reference surface at a discontinuity point (i = N) (See Section 2.10)
8	GSPR1	Station location of internal support spring, one per region
9	GUK	Spring constant, meridional direction
10	GVK	Spring constant, circumferential
11	GWK	Spring constant, normal to shell
12	GEMK	Spring constant, rotational
		When GMI = 1.0; see Section 2.8.1
15	RAI	Radial distance from axis of revolution to station 1 (L)
16	AXL	Meridional length of shell (L)
17	ANX	Angle the generator makes with the axis of revolution (degrees)
		When GMI = 2.0; see Section 2.8.2
15	RC	Radius of curvature of the generator (L)
16	ROFF	Offset distance measured from axis of revolution to center of meridional curvature (L)
17	PHIO	Initial opening angle from vertical axis (degrees)
18	PHIN	Final opening angle from vertical axis (degrees)
		When GMI = 3.0 (or -3.0); see Section 2.8.3
19	EM	Number of RIPT's given (12 minimum, 150 maximum)
20	RIPT	Discrete radial distances

DECRD Index	Name	Description and Comments
170	XIPT	Discrete axial or vertical distances (or arc lengths)
320	RCURV	Meridional radii of curvatures
470	RCURZ	Circumferential radii of curvatures GMI = 4.0, 5.0; see Section 2.8.4
796	RFF	Offset distance from axis of revolution to the parallel coordinate of the standard form
797	SPNO	Clockwise positive opening angle from the positive vertical standard form coordinate to the first station (degrees)
798	SPNN	Clockwise positive opening angle from the positive vertical standard form coordinate to the last station (degrees)
799	A	Semimajor axis parallel to the axis of revolution
800	B	Semimajor axis perpendicular to the axis of revolution GMI = ±6.0; see Section 2.8.4
796	RFF	Offset distance from axis of revolution to the parallel coordinate of the standard form
797	SPNO	Clockwise positive opening from the positive vertical standard form coordinate to the first station (degrees)
798	SPNN	Clockwise positive opening angle from the positive vertical standard form coordinate to the last station (degrees)
799	A	Distance from the directrix to the focus, positive in positive direction of the standard form

Boundary matrices, when not set by indicator, only the diagonal elements are read. The explanation below is based on the assumption that the user is familiar with Section 1.9, "Boundary Conditions".

DECRD Index	Name	Description and Comments
620	EMIX	Diagonal terms of force boundary matrix (Ω) ($i = 1$ or top of shell)
624	EM3X	Diagonal terms of displacement boundary matrix (Λ), $i = 1$
628	EM5X	Column boundary matrices (ℓ), top of open shell ($i = 1$); dimensioned for 20 Fourier components of boundary force or displacement
708	EMNI	Like EMIX at $i = N$ (or bottom boundary)
712	EMN3	Like EM3X at $i = N$ (bottom boundary)
716	EMN5	Like EM5X at $i = N$ (bottom boundary)

3.4.6 Call DECRD (SDA)

The SDA data array is set to zero before the first case and first region data are read. Succeeding regions or cases have just the T, ENT, EMT, PN, PFE, and PTH arrays zeroed. EX is set to zero on the second pass of an unsymmetrical load case. All other data will remain unchanged from the preceding region unless entered by the programmer. If there are no changes, one data card (with an index number) must be read to satisfy the call DECRD (SDA) statement.

DECRD Index	Name	Description and Comments
1	EX	Constant data indicator* $= 0$. No constants Negative - all constants. One value is entered for D, EK, E1, T, ALF, DNA, POI and the Fourier component of ENT, EMT, PFE, PTH, PN. These values are modified by the reference coefficients where applicable and the entire EN stations are filled with the constants.

---

*The constant data indicator for EX $\neq 0$ can be used only when SUM = 0. When SUM $\neq 0$, EX must be set equal to zero and normal input format following.

DECRD Index	Name	Description and Comments
		= + 1. - constant section properties and temperature loads. One value is entered for EI, POI, DNA, ALF, and T. Values for D, EK, EMT and ENT are set by Equations 33 through 36. Values may be read for D and EK by entering the data flag 1. E + 10 in SDA (26) and the D and EK values in SDA (27) and SDA (177), respectively. The program multiplies by the appropriate reference coefficients. = + 2. - constant pressure loads, no temperature loads. The Fourier component for PN, PFE and PTH are entered as data. The values are multiplied by the reference coefficients and stored for EN stations.

The following data are read directly into the SDA array only when EX is nonzero, exceptions noted.

DECRD Index	Name	Description and Comments
25	POI	Poisson's ratio (ν). Not entered for EX = +2.
26	D	Membrane stiffness (bE_oh_o). Not entered for positive EX, except for data flag use explained in EX = +1., above.
176	EK	Bending stiffness ($dE_oh_o^3$). Same as D.
326	ENT	Thermal load ($t_T\sigma_oh_o$). Negative EX only.
476	EMT	Thermal moment ($m_T\sigma_oh_o^3$). Negative EX only.
626	PFE	Fourier component for surface load applied in meridional direction ($P_\xi a/\sigma_oh_o$). Read for negative EX or EX = +2.
776	PTH	Same as PFE, circumferential direction
926	PN	Same as PFE, normal direction

DECRD Index	Name	Description and Comments
1076	E1	Modulus of elasticity (E). Read when EX is negative or equal to +1.
1226	T	Temperature differential (0° reference temperature). EX neg. or +1.
1376	ALF	Coefficient of thermal expansion (α). EX negative or +1.
1526	DNA	Distance from neutral axis. (Value will be negative for inner surface.) EX negative or +1.

These data cards (with a "-" in column 1 of the last one) will be succeeded by the following:

When EX is	
-1.	Next region's GDA, geometry data
+1.	This region's DLD, pressure loads data
+2.	This region's DAL, Section properties data
0.	This region's DLD, then DAL data

3.4.7 Call DECRD (DLD)

The DLD data array is zeroed each time before the above statement is executed. This means that all DLD data must be repeated for multiple region or multiple case runs.

DECRD Index	Name	Description and Comments
1	PILD	Pressure loads indicator for PFETB, PTHTB, PNTB = 1. constants = 2. Fourier components given = 3. Fourier summing, symmetrical
2	TIBT	Temperature distribution indicator for inner surface (TBOT) (Same as PILD)
3	TITP	Temperature distribution indicator for outer surface (TTOP) (Same as PILD)

DECRD Index	Name	Description and Comments
4	ENTH	Number of finite sums taken to evaluate Fourier inversion integral for pressure or temperature coefficients. For most cases, best results obtained by setting equal to maximum value of 91.
5	PFETB	Table for PFE load. The array is dimensioned as 200 and its format is dependent on PILD, as explained below—TAB setup, Section 3.4.7.1
205	PTHTB	Table for PTH load. Like PFETB
405	PNTB	Table for PN load. Like PFETB
605	TBØT	Table for temperatures on the inner surface. Dimension is 200; format determined by TIBT
805	TTØP	Table for outer surface temperature. Dimension is 200; format determined by TITP
1005	PSIO	Angle at which line load is applied at a junction point (see Figure 1-10)
1006	PD	Magnitude of line loads applied at a junction point. Consecutive locations are used for succeeding Fourier components, 11 maximum
1026	EMD	Line moment applied at a junction (11 Fourier components possible)

Don't forget the "-" in column one of the last card.

3.4.7.1 Tab Setup

All loads tables—PFETB, PTHTB, PNTB, TBOT, and TTOP—are dimensioned 200. Where Fourier summing is desired, the values are read for all Fourier components (ENF's) at the same time. The format of the tables for PFE, PTH, and PN will depend on the value assigned to PILD, while that of TBOT and TTOP are determined by TIBT and TITP, respectively.

TAB(I) Tables for all loads (temperature) and all ENF's

Indicator = 1

TAB(I)	Constant value for first ENF
TAB(I+1)	Constant value for second ENF
.	Etc.
.	
.	

Indicator = 2

TAB(I)	Number of ENF's
TAB(I+1)	1st ENF value
TAB(I+2)	Number of meridional stations where loads are entered
TAB(I+3)	Station No. = 1 ** must be 1.
TAB(I+4)	Load at station 1
TAB(I+5)	Second station, e.g. 10.
TAB(I+6)	Load at station 10.,
.	etc., with station numbers and values interlaced.
.	
.	**The last station must be EN, GDA (2)
.	

TAB(2* TAB(I+2)+4) will be like TAB(I+1), i.e., the second ENF value. Repeat the pattern.

Indicator = 3

TAB(I)	Number of theta rays (circumferential stations) included in the table
TAB(I+1)	First theta value (degrees) ** must be 0.
TAB(I+2)	Number of stations to describe the first theta ray ** Must include all stations listed for all theta rays (20 maximum)
TAB(I+3)F	Stations and values interlaced in same manner as for Indicator = 2. Rules regarding first and last stations apply to all theta rays
.	
.	
.	
.	

TAB(2* TAB(I+2)+4)F will be like TAB(I+1) for the second theta and the pattern repeats from there. **It is not necessary to include all stations from theta ray one in theta ray two and the succeeding rays but stations 1 and EN must be among those chosen. **The last theta value must be 180..

The table entered for an indicator 3 will be used to form a matrix, NFE x NTH, where NFE is equal to the number of stations given in TAB(I+2) and NTH is equal to ENTH, i.e., DLD (4).

The matrix is formed by double, linear interpolation of the values. The interpolation subroutine, DINTRP, will select the lower or upper bound when a value is off an end of a theta ray and continue after printing:

```
LIMITS OF TABLE EXCEEDED BY ARGUMENT  ±x.xxxxE±xx
±x.xxxxE±xx  VALUE USED FROM TABLE
```

This, of course, wastes time and will not occur if stations along each theta ray start with 1. and end with EN. A more serious error is made when the first theta ray is not 0.0 degrees and the last 180.0 degrees. The resulting printout will read:

```
ARGUMENT EXCEEDS EXTENT OF TABLE IN DINTRP
         ARGUMENT = ±x.xxxxE±xx   (6 per line)
         TABLE VALUES x.xxxxE±xx  ------
                                  ------
```

and the job is terminated.

When EX is	Next data will be
0.	This region's DAL, section properties data
-1.	Next region's DGA, geometry data
-1. or 2.	(Should not have had any DLD data.)

3.4.8 Call DECRD (DAL)

The DAL data array is zeroed each time before the above statement is executed. This means that all DAL data must be repeated for multiple region or multiple case runs.

DECRD Index	Name	Description and Comments
1	ELAY	Number of layers (6 maximum)
2	STRIX	Layer number for second stress print
3	EIFH	Thickness indicator = +1. constants all stations in a layer = -1. discrete values given at THSTA stations

DECRD Index	Name	Description and Comments
4	ENØTH	Number of thickness stations
5	THSTA	Station numbers at which thicknesses are given. These are the same for all layers. (20 maximum) First one = 1., last one = EN.
25	TH	Thicknesses at stations, layers

**The TH array is dimensioned (20 x 6). When EIFH = +1. The constant for each layer may be entered in consecutive locations, i.e., the thickness for layer one at DECRD index, 25, thickness for layer two at 26, etc.

When thickness varies along a layer (EIFH = -1) and values are entered at thickness stations (THSTA), they must be entered according to FORTRAN doubly subscripted arrays. Station 1 on the second layer will have a DECRD index 20 locations away from station 1 on layer one (the inner layer). For any given station and layer, the DECRD index = 24 + 20* (layer no. —1) + sta. no. (See also the example for entering gradients.)

DECRD Index	Name	Description and Comments
145	ENMAT	Number of materials considered in problem (3 maximum)
146	EMAT	Material indicator/layer (1, 2, or 3)
152	PØIS	Poisson's ratio/layer

The Materials Tables data (DECRD indices 158 to 284) for all materials should be entered with the data for the first region which uses DAL data, whether that region uses all given materials or not.

DECRD Index	Name	Description and Comments
158	ENE1	Number of Young's moduli for the first material (10 maximum)
159	TMPE1	Temperatures at which Young's moduli are given, first material (ENE1 of them)

DECRD Index	Name	Description and Comments
169	YM1	Young's modulus for first material
179	ENE2	Same as ENE1, second material
180	TMPE2	Same as TMPE1, second material
190	YM2	Same as YM1, second material
200	ENE3	Same as ENE1, third material
201	TMPE3	Same as TMPE1, third material
211	YM3	Same as YM1, third material

**When there are no temperature loads, the Young's modulus is considered constant and should be entered at DECRD indices 169, 190, and 211 for materials 1, 2, and 3, respectively.

DECRD Index	Name	Description and Comments
221	ENA1	Number of thermal expansion coefficient for first material, 10 maximum
222	TMPA1	Temperatures at which thermal expansion coefficients are given. First material, ENA1 of them
232	ALF1	Thermal expansion coefficients for first material
242	ENA2	As ENA1, second material
243	TMPA2	As TMPA1, second material
253	ALF2	As ALF1, second material
263	ENA3	As ENA1, third material
264	TMPA3	As TMPA1, third material
274	ALF3	As ALF1, third material

**TMPE1, TMPE2, TMPE3, TMPA1, TMPA2, and TMPA3 are used by the curve-fitting routine CODIMA, and so the temperatures should be listed in algebraic ascending order and should bound expected temperatures for all regions.

DECRD Index	Name	Description and Comments
284	ENØGR	Number of gradient stations (10 maximum)
285	GSTA	Stations at which temperature gradients are given. Same for each interface. First one = 1. Last one = EN
295	GR	Gradients at GSTA stations and "internal" interfaces, counting from the first interface (next to the inner surface) up to and including the last interface (below the outer surface of the shell). Values are given as ratio of the total differential between top and bottom surface temperatures.

**When the gradients are constant along an interface, ENOGR is entered as 1. and the gradient values are entered in the GR array in consecutive locations, each representing the value to be used for one interface. It is not necessary to enter GSTA values.

When the gradients vary along an interface, and gradient stations (GSTA) are given, the gradients themselves must be entered according to the way FORTRAN stores doubly subscripted arrays. GR (stations, gradient interfaces) = GR (10, 5).

For example, ENOGR = 4, ELAY = 3., then the DECRD indices for the GR array would be

GSTA / Layer	1.	10.	25.	EN
1	295	(296)	(297)	(298) entered on one card
2	305	(306)	(307)	(308) entered on next card
3	315	(316)	(317)	(318) entered on third card

The DECRD index for any layer and station = 294 + 10 (layer no. —1) + sta.

The last DAL data card should have a minus (-) in column 1. The geometry data, GDA, for the next region will normally follow except for subsequent cases where PTHI may not be zero.

When PTHI is negative, the geometry data remains the same and the next cards will be SDA type. If one desires to enter values in the EM5X or EMN5 boundary matrices without entering the GEOM subroutine, he may use SDA (2458) and SDA (2494), respectively, when SUM = 0.; or, when summing is desired, the values for the first Fourier component will be entered in SDA (2458) and SDA (2494) but succeeding Fourier components for the upper boundary in SDA (780) and lower boundary in SDA (930).

When PTHI is positive the DAL data will be followed by DLD, loads data for the next region. A positive PTHI does not permit a change in the EM5X and EMN5 boundary matrices.

3.5 OUTPUT FORMAT

Following are sample pages and a description of the output of the program. The sample output represents some of the results obtained from the sample problem discussed in Section 3.6. Due to amount of output information, only a portion of the results will be used to illustrate the output format. Additional results are reported in Section 3.6. The page numbers indicate the start of new pages of the computer output (i.e., the first print wheel has the carriage control character 1) and do not necessarily correspond to the actual page numbers of the computer output. The latter is a function of the number of meridional stations, the number of regions into which the shell has been divided and the value assigned to the print indicator, PFLAG, entered with the geometry data, GDA. These page numbers and the circled letters that correspond to remarks in the description are not printed by the computer. The link where the printing occurs and the EFN (external formula number) of the FORMAT statements are given for cross-reference with the program listings (Section 3.9).

Output page 1		Always printed EXEC
A	Three title cards. These cards are printed exactly as entered on the data sheets.	
B	This space is available for other pertinent comments that would not fit the three title cards but that will be useful from a documentation point of view. It is a convenient place to include a sketch of the model assumed in setting up the problem, such as identifying the ends and junctions of various regions and showing the loads and reactions together with their respective points of application.	(21)

Output page 2 Always printed EXEC

A This is the value entered as ENFO, the initial Fourier component.

B There are 12 values printed for Fourier components, but as stated in the input format, only 10 values in addition to the ENFO are provided for. The last one is used as a program indicator and in fact will be "wiped out" by the program, if entered.

(32)

C Space is provided for 10 thetas. The eleventh one is used as an indicator. See B.

D When SUM = 0., it is not necessary to enter any ENFOR data.

E When SUM = 0. only three or fewer ENFOR's should be chosen. This location like B and C should always be -1.0000E 10 and will be set to this number by the machine.

Output page 3 Always printed GEOM

A Region number will depend on how the data cards were stacked, i.e., the first set of data entered is called "1", the second set "2", etc.

B The type of shell is indicated, depending on the value read in for the geometry indicator, GMI. (32, 49 or 90)

C The value 1.0000E 10 indicates a discontinuity boundary. Any other values were entered as data. See input format for GDA (page)

D This data will vary with the GMI indicator.

E These parameters, together with the finite difference increment, DEL, are computed by the GEOM subroutine. They are printed at each of the N meridional stations. (126)

R	Figure 1.1	Section 1.3
X	Figure 1.1	Section 1.3
WFE	Equation 4	Section 1.3
WTH	Equation 3	Section 1.3
GAMA	Equation 5	Section 1.3
RHO		Section 1.3

```
BRANCHED SHELL SAMPLE PROBLEM FOR USERS MANUAL ** AUGUST 19, 1965

FOUR REGIONS * SPHERE - CONE - CONE - CYLINDER * UNSYMMETRICAL PRESSURE      ⓐ

LOADING, TEMPERATURE LOADS, LAYERED REGIONS, BOUNDARY FORCE
```

Ⓑ

Output Page 1

```
                                        GENERAL DATA

NO. OF SHELL REGIONS (EKK)  =   4.0000E 00

FOURIER COMPONENTS (ENFI)  -
                       (A)
                      0.0000E-39   1.0000E 00  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10
                     -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10
                                                                                          (B)
PRINT ANGLES (THETA)  -

                      0.0000E-39   9.0000E 01   1.8000E 02  -1.0000E 10  -1.0000E 10  -1.0000E 10
                     -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10
                                                                            (C)
CONSTANTS  -

AO   =   1.0000E 00    HO   =   1.0000E 00    FO   =   1.0000E 00    SIGO  =   1.0000E 00

SUM  =   1.0000E 00    PIXI  =  1.0000E 00    PTHI  =   0.0000E-39

PRINT ENFS (ENFOR)  -  (D)            (E)
                      0.0000E-39   1.0000E 00  -1.0000E 10  -1.0000E 10



     (FLAG -1.0E+10 INDICATES LAST ENFI, ENFOR, AND THETA VALUES.)
```

Output Page 2

```
                                             Ⓐ        Ⓑ
                  GEOMETRY DATA FOR REGION   1   (SPHERE-TOROID)

NO. OF STATIONS               N     =    1.2100E 02

FINITE DIFFERENCE INCR.       DEL   =    7.0395E-02

BOUNDARY CONDITIONS           BCIT  =    9.0000E 00
                              BCIR  =    1.0000E 01  —Ⓒ

DISCONTINUITY CONDITIONS      PSI   =    0.0000E-39
                              ECX   =    0.0000E-39

SPRING CONDITION              SPRL  =    0.0000E-39
UK   =    0.0000E-39     VK    =    0.0000E-39     WK    =    0.0000E-39     MK    =    0.0000E-39

OTHER DATA
PFLAG=   -1.0000E 00     GEOMI=    2.0000E 00
Ⓓ RC    =    6.0520E 00        ROFF   =   0.0000E-39        PHIO   =   0.0000E-39        PHIN   =   9.0000E 01

  I   Ⓔ   R(I)               X(I)               WFE(I)             WTH(I)             GAMA(I)            RHO(I)

  1    0.0000000E-39    0.0000000E-39    1.6528925E-01    1.6528925E-01    1.0000000E 10    0.0000000E-39
  2    7.0393356E-02    4.0951557E-04    1.6528925E-01    1.6528925E-01    1.4204606E 01    7.0393356E-02
  3    1.4077718E-01    1.6381074E-03    1.6528925E-01    1.6528925E-01    7.1013412E 00    1.4077718E-01
  4    2.1114195E-01    3.6855049E-03    1.6528925E-01    1.6528925E-01    4.7331589E 00    2.1114195E-01
  5    2.8147813E-01    6.5514828E-03    1.6528925E-01    1.6528925E-01    3.5487469E 00    2.8147813E-01
  6    3.5177620E-01    1.0235635E-02    1.6528925E-01    1.6528925E-01    2.8379433E 00    3.5177620E-01
  7    4.2202565E-01    1.4737512E-02    1.6528925E-01    1.6528925E-01    2.3636934E 00    4.2202565E-01
  8    4.9221995E-01    2.0056436E-02    1.6528925E-01    1.6528925E-01    2.0248315E 00    4.9221995E-01
  9    5.6234662E-01    2.6191732E-02    1.6528925E-01    1.6528925E-01    1.7709245E 00    5.6234662E-01
 10    6.3239717E-01    3.3142543E-02    1.6528925E-01    1.6528925E-01    1.5725970E 00    6.3239717E-01
 11    7.0236209E-01    4.0907923E-02    1.6528925E-01    1.6528925E-01    1.4141092E 00    7.0236209E-01
  ↕        ↕                 ↕                  ↕                  ↕                  ↕                  ↕
114    5.8528591E 00    4.5181657E 00    1.6528925E-01    1.6528925E-01    4.3259013E-02    5.8528591E 00
115    5.8702862E 00    4.5863690E 00    1.6528925E-01    1.6528925E-01    4.1210785E-02    5.8702862E 00
116    5.8869185E 00    4.6547703E 00    1.6528925E-01    1.6528925E-01    3.9173358E-02    5.8869185E 00
117    5.9027538E 00    4.7233605E 00    1.6528925E-01    1.6528925E-01    3.7147689E-02    5.9027538E 00
118    5.9177900E 00    4.7921305E 00    1.6528925E-01    1.6528925E-01    3.5132524E-02    5.9177900E 00
119    5.9320250E 00    4.8610706E 00    1.6528925E-01    1.6528925E-01    3.3127266E-02    5.9320250E 00
120    5.9454569E 00    4.9301717E 00    1.6528925E-01    1.6528925E-01    3.1131471E-02    5.9454569E 00
121    5.9580439E 00    4.9994245E 00    1.6528925E-01    1.6528925E-01    2.9146638E-02    5.9580439E 00
```

Output Page 3

Output page 4 Printed on negative PFLAG in DATLDS (451)

There is no sample output page for this, since it would be used very infrequently for diagnostic purposes to check the "summing matrix" that results from linear double interpolation of the load distribution on the shell.

The matrix is dimensioned NFE by NTH, where NFE is the number of stations entered in the table along the first theta ray (TAB (I+2)) when the indicator is set at option 3 (20 maximum); and NTH is the fixed point form of DLD(4), ENTH (see Section 3.4.7), the number of theta increments to sum.

This summing area, called TEMP, is printed station-wise (column-wise), eight per line.

Output page 5 PFLAG ≠ 0., DATLDS (97)

The output sample for this page represents results printed out for the tables. It would be used strictly as a check of the data inputted in PFETB, PTHTB, PNTB, TBOT and TTOP. (See Section 3.4.7.) The format would appear as follows:

```
                 LOADS TABLES FOR REGION 1

         I     PFE     PTH     PN     TBOT     TTOP

         1
         2
         .
         .
         .
         .
        200
```

Output page 6 PFLAG ≠ 0., DATLDS (851)

A	Meridional stations, 19 or 20 of them, chosen equally spaced between 1 and EN
B	TBOT, temperature on the bottom or inner surface TTOP, temperature on the top or outer surface. In the example shown the bottom surface temperature data was constant, and outer surface varied linearly along the meridian, i.e., TIBT = 1, TITP = 2.

```
                              LOADS TABLES FOR REGION  1

  I        PFE              PTH               PN               TBAT             TTOD

  1   0.0000000E-39    0.0000000E-39    2.0000000E 00    1.1000000E 02    2.0000000E 00
  2   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
  3   0.0000000E-39    0.0000000E-39    4.0000000E 00    0.0000000E-39    2.0000000E 00
  4   0.0000000E-39    0.0000000E-39    1.0000000E 00    0.0000000E-39    1.0000000E 00
  5   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
  6   0.0000000E-39    0.0000000E-39    5.8000000E 01    0.0000000E-39    1.2100000E 02
  7   0.0000000E-39    0.0000000E-39   -7.5000000E 00    0.0000000E-39    5.0000000E 01
  8   0.0000000E-39    0.0000000E-39    8.8300000E 01    0.0000000E-39    1.0000000E 00
  9   0.0000000E-39    0.0000000E-39   -9.1900001E 00    0.0000000E-39    2.0000000E 00
 10   0.0000000E-39    0.0000000E-39    1.2100000E 02    0.0000000E-39    1.0000000E 00
 11   0.0000000E-39    0.0000000E-39   -1.0000000E 01    0.0000000E-39    0.0000000E-39
 12   0.0000000E-39    0.0000000E-39    1.0000000E 00    0.0000000E-39    1.2100000E 02
 13   0.0000000E-39    0.0000000E-39    4.0000000E 00    0.0000000E-39    0.0000000E-39
 14   0.0000000E-39    0.0000000E-39    1.0000000E 00    0.0000000E-39    0.0000000E-39
 15   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 16   0.0000000E-39    0.0000000E-39    5.8000000E 01    0.0000000E-39    0.0000000E-39
 17   0.0000000E-39    0.0000000E-39   -3.7500000E 00    0.0000000E-39    0.0000000E-39
 18   0.0000000E-39    0.0000000E-39    8.8000000E 01    0.0000000E-39    0.0000000E-39
 19   0.0000000E-39    0.0000000E-39   -4.5950000E 00    0.0000000E-39    0.0000000E-39
 20   0.0000000E-39    0.0000000E-39    1.2100000E 02    0.0000000E-39    0.0000000E-39
 21   0.0000000E-39    0.0000000E-39   -5.0000000E 00    0.0000000E-39    0.0000000E-39
 22   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 23   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 24   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 25   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 26   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 27   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 28   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 29   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 30   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 31   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 32   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 33   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 34   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 35   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 36   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 37   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 38   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
```

Output Page 5

```
FOR REGION 1 THE TEMPERATURE LOADS WERE

 STA.Ⓐ       THOT    Ⓑ      TEMP

   1.0    1.1000E 02    0.0000E-39
   8.0    1.1000E 02    2.9167E 00
  15.0    1.1000E 02    5.8333E 00
  22.0    1.1000E 02    8.7500E 00
  29.0    1.1000E 02    1.1667E 01
  36.0    1.1000E 02    1.4583E 01
  43.0    1.1000E 02    1.7500E 01
  50.0    1.1000E 02    2.0417E 01
  57.0    1.1000E 02    2.3333E 01
  64.0    1.1000E 02    2.6250E 01
  71.0    1.1000E 02    2.9167E 01
  78.0    1.1000E 02    3.2083E 01
  85.0    1.1000E 02    3.5000E 01
  92.0    1.1000E 02    3.7917E 01
  99.0    1.1000E 02    4.0833E 01
 106.0    1.1000E 02    4.3750E 01
 113.0    1.1000E 02    4.6667E 01
 120.0    1.1000E 02    4.9583E 01
 121.0    1.1000E 02    5.0000E 01
```

Output Page 6

**Pages 4, 5 and 6, to reiterate, can be printed only if the DATLDS subroutine has been entered. (EX will be 0. or +1. or, for a succeeding case, PTHI will be greater than zero.)

Output page 7 PFLAG ≠ 0., DATLYR

A First, second, and third materials. Curves are dimensioned for 10 possible values. Zeroes fill the locations where no entries have been made.

B The meridional station numbers given here are a combination of those set up in DATLDS for the temperature loads (see output page 6) and the thickness stations, THSTA, read as data or set to 1. and EN when the thickness is constant, as it was in the example.

C The temperatures indicate a value at the inner face of the layer (440)

D Printed for all values of PFLAG from here to "Output page 8."

E One value of Poisson's ratio per layer, read
1st layer 2nd 3rd
4th 5th 6th (591)
Material indicators have the same format.

F Gradients are entered for interfaces other than the inner and outer faces and at stations common to all, thus the printout indicates interfaces
2 3 4 5 6
where 1 and 7 would indicate the inner and outer faces, respectively.

DATLNK (102)

G When the DATLYR subroutine has not been entered because EX = ± 1. the Section and Material Properties output will consist of just the printout from this point to "Output page 8."

H POI, Poisson's ratio, inner layer
POI2, Poisson's ratio for second stress

Print Symbol	Math Symbol and Equation	Definition
D	b Equation 33, Section 1.7	Membrane stiffness
EK	d Equation 34, Section 1.7	Bending stiffness
E	E	Modulus of elasticity (E1)
ALF		Thermal expansion coefficient
DNA		Distance from the neutral axis to the inner surface
T	T Equation 26, Section 1.7	Temperature differential

**For succeeding Fourier components none of the Section and Material Properties are printed except when PFLAG $\neq$ 0.

Output page 8 Always printed DATLNK (104)

A	ENF, current Fourier component
B	Current Fourier component for a force or moment applied at a junction point, EN.
C	Mechanical and thermal loads at each meridional station

Print Symbol	Math Symbol and Equation	Definition
P(PHI)	**Equation 25, Section 1.7**	**Pressure in the meridional direction**
P(THETA)	**Equation 25, Section 1.7**	**Pressure in the circumferential direction**
P(N)	**Equation 25, Section 1.7**	**Normal pressure**
ENT	**Equation 35, Section 1.7**	**Temperature load**
EMT	**Equation 36, Section 1.7**	**Temperature moment**

```
                    SECTION AND MATERIAL PROPERTIES - REGION   2


   THICKNESS INDICATOR        =   1.0000E 00

                             CURVES OF TEMPERATURE VS. YOUNGS MODULUS

      TEMP          Ⓐ YM1               TEMP          Ⓐ YM2               TEMP          Ⓐ YM3
  -1.000000E 03    6.500000E 06    -1.000000E 03    1.000000E 07     0.000000E-39     0.000000E-39
   0.000000E-39    6.500000E 06     1.000000E 03    1.000000E 07     0.000000E-39     0.000000E-39
   1.000000E 02    6.500000E 06     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   1.000000E 03    6.000000E 06     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39

                          CURVES OF TEMPERATURE VS. THERMAL EXPANSION COEF.

      TEMP            ALF1              TEMP            ALF2              TEMP            ALF3
  -1.000000E 03    1.400000E-05    -1.000000E 03    1.330000E-05     0.000000E-39     0.000000E-39
   1.000000E 03    1.300000E-05     1.000000E 03    1.330000E-05     0.000000E-39     0.000000E-39
   1.500000E 03    1.200000E-05     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39
   0.000000E-39    0.000000E-39     0.000000E-39    0.000000E-39     0.000000E-39     0.000000E-39

                     TABLE OF STATIONS VS. TEMP. AND THICKNESSES, LAYER 1

                      Ⓑ STA.         Ⓒ TEMP           THK.
                      1.000000E 00    1.500000E 02    5.000000E-02
                      7.000000E 00    1.500000E 02    5.000000E-02
```

Output Page 7

```
   1.30000E 01     1.50000E 02     5.00000E-02
   1.90000E 01     1.50000E 02     5.00000E-02
   2.50000E 01     1.50000E 02     5.00000E-02
   3.10000E 01     1.50000E 02     5.00000E-02
   3.70000E 01     1.50000E 02     5.00000E-02
   4.30000E 01     1.50000E 02     5.00000E-02
   4.90000E 01     1.50000E 02     5.00000E-02
   5.50000E 01     1.50000E 02     5.00000E-02
   6.10000E 01     1.50000E 02     5.00000E-02
   6.70000E 01     1.50000E 02     5.00000E-02
   7.30000E 01     1.50000E 02     5.00000E-02
   7.90000E 01     1.50000E 02     5.00000E-02
   8.50000E 01     1.50000E 02     5.00000E-02
   9.10000E 01     1.50000E 02     5.00000E-02
   9.70000E 01     1.50000E 02     5.00000E-02
   1.03000E 02     1.50000E 02     5.00000E-02
   1.09000E 02     1.50000E 02     5.00000E-02


TABLE OF STATIONS VS. TEMP. AND THICKNESSES, LAYER 2

       STA.            TEMP            THK.
   1.00000E 00     1.30000E 02     1.00000E-01
   7.00000E 00     1.30000E 02     1.00000E-01
   1.30000E 01     1.30000E 02     1.00000E-01
   1.90000E 01     1.30000E 02     1.00000E-01
   2.50000E 01     1.30000E 02     1.00000E-01
   3.10000E 01     1.30000E 02     1.00000E-01
   3.70000E 01     1.30000E 02     1.00000E-01
   4.30000E 01     1.30000E 02     1.00000E-01
   4.90000E 01     1.30000E 02     1.00000E-01
   5.50000E 01     1.30000E 02     1.00000E-01
   6.10000E 01     1.30000E 02     1.00000E-01
   6.70000E 01     1.30000E 02     1.00000E-01
   7.30000E 01     1.30000E 02     1.00000E-01
   7.90000E 01     1.30000E 02     1.00000E-01
   8.50000E 01     1.30000E 02     1.00000E-01
   9.10000E 01     1.30000E 02     1.00000E-01
   9.70000E 01     1.30000E 02     1.00000E-01
   1.03000E 02     1.30000E 02     1.00000E-01
   1.09000E 02     1.30000E 02     1.00000E-01
```

Output Page 7 (Cont)

```
TABLE 4 STATIONS VS. TEMP. AND THICKNESSES, LAYER 3

       STA.              TEMP             THK.
   1.00000E 00       1.14000E 02      5.00000E-02
   7.00000E 00       1.14000E 02      5.00000E-02
   1.30000E 01       1.14000E 02      5.00000E-02
   1.90000E 01       1.14000E 02      5.00000E-02
   2.50000E 01       1.14000E 02      5.00000E-02
   3.10000E 01       1.14000E 02      5.00000E-02
   3.70000E 01       1.14000E 02      5.00000E-02
   4.30000E 01       1.14000E 02      5.00000E-02
   4.90000E 01       1.14000E 02      5.00000E-02
   5.50000E 01       1.14000E 02      5.00000E-02
   6.10000E 01       1.14000E 02      5.00000E-02
   6.70000E 01       1.14000E 02      5.00000E-02
   7.30000E 01       1.14000E 02      5.00000E-02
   7.90000E 01       1.14000E 02      5.00000E-02
   8.50000E 01       1.14000E 02      5.00000E-02
   9.10000E 01       1.14000E 02      5.00000E-02
   9.70000E 01       1.14000E 02      5.00000E-02
   1.03000E 02       1.14000E 02      5.00000E-02
   1.09000E 02       1.14000E 02      5.00000E-02


       STATION VS. TEMPERATURE, OUTER FACE

              STA.            TEMP
          1.00000E 00     1.10000E 02
          7.00000E 00     1.10000E 02
          1.30000E 01     1.10000E 02
          1.90000E 01     1.10000E 02
          2.50000E 01     1.10000E 02
          3.10000E 01     1.10000E 02
          3.70000E 01     1.10000E 02
          4.30000E 01     1.10000E 02
          4.90000E 01     1.10000E 02
          5.50000E 01     1.10000E 02
          6.10000E 01     1.10000E 02
          6.70000E 01     1.10000E 02
          7.30000E 01     1.10000E 02
```

Output Page 7 (Cont)

```
                                        7.00000E 01     1.10000E 02
                                        8.50000E 01     1.10000E 02
                                        9.10000E 01     1.10000E 02
                                        9.70000E 01     1.10000E 02
                                        1.03000E 02     1.10000E 02
                                        1.09000E 02     1.10000E 02

Ⓓ NO. OF LAYERS        (ELAY)  =   3.0000E 00

  NO. OF MATERIALS     (ENMAT) =   2.0000E 00

  POISSONS RATIOS      (POIS)  =   Ⓔ 3.0000E-01        3.5000E-01        3.0000E-01
                                     0.0000E-39        0.0000E-39        0.0000E-39

  MATERIAL IND.        (EMAT)  =   Ⓔ 2.0000E 00        1.0000E 00        2.0000E 00
                                     0.0000E-39        0.0000E-39        0.0000E-39

  GRADIENT TABLES

    STA.                                Ⓕ  GRADIENTS AT INNER INTERFACES
 1.000000E 00     5.000000E-01     9.000000E-01     0.000000E-39     0.000000E-39     0.000000E-39
 1.090000E 02     5.000000E-01     9.000000E-01     0.000000E-39     0.000000E-39     0.000000E-39

      Ⓖ  EX =    0.0000E-39         POI =   3.0000E-01      Ⓗ   POI2 =   3.0000E-01

                    LAYER NO. FOR SECOND STRESS PRINT =    3.0000E 00

 I   Ⓘ  D(I)             EK(I)            E(I)             ALF(I)            DNA(I)            T(I)

 1    1.8394678E 06    7.0273950E 03    1.0000000E 07    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 2    1.8394678E 06    7.0273950E 03    9.9999999E 06    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 3    1.8394678E 06    7.0273950E 03    9.9999999E 06    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 4    1.8394678E 06    7.0273950E 03    1.0000000E 07    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 5    1.8394678E 06    7.0273950E 03    9.9999999E 06    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 6    1.8394678E 06    7.0273950E 03    9.9999999E 06    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 7    1.8394678E 06    7.0273950E 03    1.0000000E 07    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 8    1.8394678E 06    7.0273950E 03    9.9999999E 06    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 9    1.8394678E 06    7.0273950E 03    9.9999999E 06    1.3300000E-05    -1.0000064E-01    1.5000000E 02
 109
```

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D These matrices are the Ω and Λ matrices of Equation 47, Section 1.9. They are printed for boundary condition indicators equal to 1. through 6.; thus, a set printed with the last region on the shell would be for a bottom boundary. Branched shells may have several top boundary prints but any closed apex regions (BCITP = 9.) will not be printed.

Output page 9 SUMS (733)

A Current circumferential angle

B Current Fourier component. Results are for this component only or represent the Fourier sums to this component, depending on whether SUM = 0. or SUM ≠ 0., respectively.

Print Symbol	Math Symbol and Equation	Definition
U		Meridional displacement
V	Equation 21, Section 1.3.5	Circumferential displacement
W	Figure 3a, Section 1.3.4	Normal displacement
M(PHI)		Meridional bending moment per unit length
M(THETA)	Equation 20, Section 1.3.5 Figure 2c, Section 1.3.4	Circumferential bending moment per unit length
M(PHI, THETA)		Bending moment per unit length, shear

Output page 10

A

Print Symbol	Math Equation and Symbol	Definition
Q(PHI) Q(THETA)	Figure 2b, Section 1.3.4	Transverse forces per unit length
N(PHI)		Meridional membrane force per unit length
N(THETA)	Equation 19, Section 1.3.5 Figure 2a, Section 1.3.4	Circumferential membrane force per unit length
N(PHI, THETA)		Membrane force per unit length, shear

```
                    LOADS   REGION   1          ENF =   0.0000E-39
                                                              Ⓐ
                              DISCONTINUITY CONDITIONS
      P(FORCE) =   1.6000E 01  Ⓑ    P(MOMENT) =   0.0000E-39      ANGLE(PSIO) =  -1.0000E 01

                              MECHANICAL AND THERMAL LOADS

  I    Ⓒ   P(PHI)          P(THETA)          P(N)           ENT(1)          EMT(2)

  1     0.0000E-39      0.0000E-39      0.0000E-39     1.0450E 03     -1.7417E 01
  2     0.0000E-39      0.0000E-39     -1.8001E-01     1.0490E 03     -1.7351E 01
  3     0.0000E-39      0.0000E-39     -3.5930E-01     1.0529E 03     -1.7285E 01
  4     0.0000E-39      0.0000E-39     -5.3485E-01     1.0569E 03     -1.7219E 01
  5     0.0000E-39      0.0000E-39     -7.0967E-01     1.0608E 03     -1.7153E 01
  6     0.0000E-39      0.0000E-39     -8.8277E-01     1.0648E 03     -1.7087E 01
  7     0.0000E-39      0.0000E-39     -1.0541E 00     1.0687E 03     -1.7021E 01
  8     0.0000E-39      0.0000E-39     -1.2238E 00     1.0727E 03     -1.6955E 01
  9     0.0000E-39      0.0000E-39     -1.3917E 00     1.0767E 03     -1.6889E 01
 10     0.0000E-39      0.0000E-39     -1.5578E 00     1.0806E 03     -1.6823E 01
 11     0.0000E-39      0.0000E-39     -1.7223E 00     1.0846E 03     -1.6757E 01
 12     0.0000E-39      0.0000E-39     -1.8850E 00     1.0885E 03     -1.6691E 01
 13     0.0000E-39      0.0000E-39     -2.0460E 00     1.0925E 03     -1.6625E 01
 14     0.0000E-39      0.0000E-39     -2.2052E 00     1.0965E 03     -1.6559E 01
 15     0.0000E-39      0.0000E-39     -2.3628E 00     1.1004E 03     -1.6493E 01
 16     0.0000E-39      0.0000E-39     -2.5186E 00     1.1044E 03     -1.6427E 01
 17     0.0000E-39      0.0000E-39     -2.6726E 00     1.1083E 03     -1.6361E 01
 18     0.0000E-39      0.0000E-39     -2.8250E 00     1.1123E 03     -1.6295E 01
 19     0.0000E-39      0.0000E-39     -2.9756E 00     1.1162E 03     -1.6229E 01
 20     0.0000E-39      0.0000E-39     -3.1245E 00     1.1202E 03     -1.6163E 01
 21     0.0000E-39      0.0000E-39     -3.2716E 00     1.1242E 03     -1.6097E 01
 22     0.0000E-39      0.0000E-39     -3.4170E 00     1.1281E 03     -1.6031E 01
 23     0.0000E-39      0.0000E-39     -3.5607E 00     1.1321E 03     -1.5965E 01
 24     0.0000E-39      0.0000E-39     -3.7027E 00     1.1360E 03     -1.5899E 01
 25     0.0000E-39      0.0000E-39     -3.8429E 00     1.1400E 03     -1.5833E 01
 26     0.0000E-39      0.0000E-39     -3.9814E 00     1.1440E 03     -1.5767E 01
 27     0.0000E-39      0.0000E-39     -4.1182E 00     1.1479E 03     -1.5701E 01
 28     0.0000E-39      0.0000E-39     -4.2532E 00     1.1519E 03     -1.5635E 01
 29     0.0000E-39      0.0000E-39     -4.3865E 00     1.1558E 03     -1.5569E 01
 30     0.0000E-39      0.0000E-39     -4.5181E 00     1.1598E 03     -1.5503E 01
 31     0.0000E-39      0.0000E-39     -4.6479E 00     1.1637E 03     -1.5437E 01
 32     0.0000E-39      0.0000E-39     -4.7761E 00     1.1677E 03     -1.5372E 01
 33     0.0000E-39      0.0000E-39     -4.9024E 00     1.1717E 03     -1.5306E 01
  ↓         ↓               ↓                               ↓               ↓
 121
```

Output Page 8

```
    BOUNDARY MATRICES ***

    EM1 (OMEGA)
1.0000000E 00      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      1.0000000E 00      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      1.0000000E 00      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39


  EM3 (LAMBDA)
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      1.0000000E 00


  EM5 (L)
0.0000000E-39      0.0000000E-39      2.5000000E 01      0.0000000E-39
```

①

```
  BOUNDARY MATRICES ***

  EM1 (OMEGA)
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      1.0000000E 00


  EM3 (LAMBDA)
1.0000000E 00      0.0000000E-39      0.0000000E-39      0.0000000E-39
0.0000000E-39      1.0000000E 00      0.0000000E-39      0.0000000E-39
0.0000000E-39      0.0000000E-39      1.0000000E 00      0.0000000E-39
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39


  EM5 (L)
0.0000000E-39      0.0000000E-39      0.0000000E-39      0.0000000E-39


  LEAVING INTLD, LNK6
```

Output Page 8 (Cont)

```
                                                                          Ⓐ                 Ⓑ
         REGION  1, DEFLECTIONS AND INTERNAL LOADS, THETA =  0.0000E-39   ENF =  0.0000E-39

  Ⓒ  U(I)          V(I)          W(I)          M(PHI)        M(THETA)     M(PHI,THETA)

      2.6193E-10  -0.0000E-39   7.9396E-02   1.6920E 01   1.6920E 01   0.0000E-39
     -8.7231E-04   0.0000E-39   7.9392E-02   1.6900E 01   1.6900E 01   0.0000E-39
  3  -1.7444E-03  -0.0000E-39   7.9380E-02   1.6872E 01   1.6854E 01   0.0000E-39
  4  -2.6160E-03  -0.0000E-39   7.9359E-02   1.6846E 01   1.6813E 01   0.0000E-39
  5  -3.4873E-03  -0.0000E-39   7.9329E-02   1.6819E 01   1.6773E 01   0.0000E-39
  6  -4.3579E-03  -0.0000E-39   7.9291E-02   1.6790E 01   1.6733E 01   0.0000E-39
  7  -5.2279E-03  -0.0000E-39   7.9244E-02   1.6758E 01   1.6692E 01   0.0000E-39
  8  -6.0971E-03  -0.0000E-39   7.9187E-02   1.6724E 01   1.6650E 01   0.0000E-39
  9  -6.9654E-03  -0.0000E-39   7.9121E-02   1.6687E 01   1.6606E 01   0.0000E-39
 10  -7.8327E-03  -0.0000E-39   7.9046E-02   1.6648E 01   1.6561E 01   0.0000E-39
 11  -8.6989E-03   0.0000E-39   7.8962E-02   1.6606E 01   1.6515E 01   0.0000E-39
 12  -9.5639E-03   0.0000E-39   7.8867E-02   1.6561E 01   1.6467E 01   0.0000E-39
 13  -1.0428E-02  -0.0000E-39   7.8763E-02   1.6513E 01   1.6417E 01   0.0000E-39
 14  -1.1290E-02  -0.0000E-39   7.8650E-02   1.6464E 01   1.6366E 01   0.0000E-39
 15  -1.2150E-02  -0.0000E-39   7.8526E-02   1.6412E 01   1.6314E 01   0.0000E-39
 16  -1.3009E-02  -0.0000E-39   7.8393E-02   1.6358E 01   1.6261E 01   0.0000E-39
 17  -1.3867E-02  -0.0000E-39   7.8250E-02   1.6302E 01   1.6206E 01   0.0000E-39
 18  -1.4722E-02  -0.0000E-39   7.8097E-02   1.6244E 01   1.6150E 01   0.0000E-39
 19  -1.5575E-02  -0.0000E-39   7.7934E-02   1.6186E 01   1.6094E 01   0.0000E-39
 20  -1.6426E-02  -0.0000E-39   7.7761E-02   1.6125E 01   1.6036E 01   0.0000E-39
 21  -1.7275E-02  -0.0000E-39   7.7578E-02   1.6064E 01   1.5977E 01   0.0000E-39
 22  -1.8122E-02  -0.0000E-39   7.7385E-02   1.6002E 01   1.5918E 01   0.0000E-39
 23  -1.8966E-02  -0.0000E-39   7.7183E-02   1.5939E 01   1.5858E 01   0.0000E-39
 24  -1.9807E-02  -0.0000E-39   7.6971E-02   1.5875E 01   1.5798E 01   0.0000E-39
 25  -2.0646E-02  -0.0000E-39   7.6748E-02   1.5811E 01   1.5737E 01   0.0000E-39
 26  -2.1482E-02  -0.0000E-39   7.6517E-02   1.5746E 01   1.5675E 01   0.0000E-39
 27  -2.2314E-02  -0.0000E-39   7.6275E-02   1.5681E 01   1.5613E 01   0.0000E-39
 28  -2.3144E-02   0.0000E-39   7.6023E-02   1.5615E 01   1.5551E 01   0.0000E-39
 29  -2.3971E-02   0.0000E-39   7.5762E-02   1.5549E 01   1.5488E 01   0.0000E-39
 30  -2.4794E-02   0.0000E-39   7.5492E-02   1.5483E 01   1.5425E 01   0.0000E-39
 31  -2.5614E-02   0.0000E-39   7.5212E-02   1.5417E 01   1.5361E 01   0.0000E-39
 32  -2.6431E-02   0.0000E-39   7.4922E-02   1.5351E 01   1.5298E 01   0.0000E-39
 33  -2.7244E-02   0.0000E-39   7.4622E-02   1.5284E 01   1.5234E 01   0.0000E-39
 34  -2.8053E-02   0.0000E-39   7.4314E-02   1.5218E 01   1.5170E 01   0.0000E-39
 35  -2.8858E-02   0.0000E-39   7.3996E-02   1.5152E 01   1.5106E 01   0.0000E-39
 36  -2.9660E-02   0.0000E-39   7.3668E-02   1.5085E 01   1.5042E 01   0.0000E-39
  |      |             |             |             |             |             |
119  -7.3445E-02   0.0000E-39   2.2930E-02   9.3264E 00   9.4407E 00   0.0000E-39
120  -7.3641E-02   0.0000E-39   2.2329E-02   1.0512E 01   9.7570E 00   0.0000E-39
121  - .3832E-02  -0.0000E-39   2.1720E-02   1.1996E 01   1.0165E 01   0.0000E-39
```

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```
 I Ⓐ Q(PHI)       Q(THETA)       N(PHI)         N(THETA)       N(PHI,THETA)

 1  -2.1533E-01   0.0000E-39   -2.5438E 00   -2.5438E 00   -0.0000E-39
 2  -3.2487E-01   0.0000E-39   -2.3787E 00   -3.1980E 00   -0.0000E-39
 3  -2.5468E-01   0.0000E-39   -3.1424E 00   -4.6659E 00    0.0000E-39
 4  -2.2579E-01   0.0000E-39   -3.8541E 00   -5.9421E 00    0.0000E-39
 5  -2.3828E-01   0.0000E-39   -4.5049E 00   -7.0428E 00    0.0000E-39
 6  -2.6861E-01   0.0000E-39   -5.0988E 00   -7.9903E 00    0.0000E-39
 7  -3.0798E-01   0.0000E-39   -5.6423E 00   -8.8065E 00    0.0000E-39
 8  -3.5200E      0.0000E-39   -6.1373E 00   -9.5117E 00    0.0000E-39
 9  -3.9816E-01   0.0000E-39   -6.5902E 00   -1.0125E 01    0.0000E-39
10  -4.4485E-01   0.0000E-39   -7.0066E 00   -1.0661E 01    0.0000E-39
11  -4.9087E-01   0.0000E-39   -7.3987E 00   -1.1136E 01   -0.0000E-39
12  -5.3531E-01   0.0000E-39   -7.7421E 00   -1.1564E 01   -0.0000E-39
13  -5.7766E-01   0.0000E-39   -8.0727E 00   -1.1957E 01    0.0000E-39
14  -6.1750E-01   0.0000E-39   -8.3808E 00   -1.2324E 01    0.0000E-39
15  -6.5451E-01   0.0000E-39   -8.6670E 00   -1.2673E 01    0.0000E-39
16  -6.8859E-01   0.0000E-39   -8.9409E 00   -1.3009E 01    0.0000E-39
17  -7.1975E-01   0.0000E-39   -9.2071E 00   -1.3346E 01    0.0000E-39
18  -7.4804E-01   0.0000E-39   -9.4589E 00   -1.3676E 01    0.0000E-39
19  -7.7348E-01   0.0000E-39   -9.7004E 00   -1.4011E 01    0.0000E-39
20  -7.9617E-01   0.0000E-39   -9.9370E 00   -1.4353E 01    0.0000E-39
21  -8.1627E-01   0.0000E-39   -1.0167E 01   -1.4699E 01    0.0000E-39
22  -8.3396E-01   0.0000E-39   -1.0395E 01   -1.5057E 01    0.0000E-39
23  -8.4949E-01   0.0000E-39   -1.0621E 01   -1.5424E 01    0.0000E-39
24  -8.6297E-01   0.0000E-39   -1.0840E 01   -1.5797E 01    0.0000E-39
25  -8.7460E-01   0.0000E-39   -1.1062E 01   -1.6182E 01    0.0000E-39
26  -8.8466E-01   0.0000E-39   -1.1283E 01   -1.6576E 01    0.0000E-39
27  -8.9328E-01   0.0000E-39   -1.1491E 01   -1.6973E 01    0.0000E-39
28  -9.0053E-01   0.0000E-39   -1.1703E 01   -1.7377E 01   -0.0000E-39
29  -9.0658E-01   0.0000E-39   -1.1921E 01   -1.7791E 01   -0.0000E-39
30  -9.1166E-01   0.0000E-39   -1.2135E 01   -1.8207E 01   -0.0000E-39
31  -9.1587E-01   0.0000E-39   -1.2343E 01   -1.8628E 01   -0.0000E-39
32  -9.1930E-01   0.0000E-39   -1.2550E 01   -1.9051E 01   -0.0000E-39
33  -9.2202E-01   0.0000E-39   -1.2764E 01   -1.9475E 01   -0.0000E-39
34  -9.2418E-01   0.0000E-39   -1.2981E 01   -1.9905E 01   -0.0000E-39
35  -9.2594E-01   0.0000E-39   -1.3196E 01   -2.0331E 01   -0.0000E-39
36  -9.2737E-01   0.0000E-39   -1.3415E 01   -2.0755E 01   -0.0000E-39
37  -9.2862E-01   0.0000E-39   -1.3642E 01   -2.1179E 01   -0.0000E-39
38  -9.2978E-01   0.0000E-39   -1.3868E 01   -2.1607E 01   -0.0000E-39
39  -9.3089E-01   0.0000E-39   -1.4085E 01   -2.2026E 01   -0.0000E-39
40  -9.3192E-01   0.0000E-39   -1.4298E 01   -2.2435E 01   -0.0000E-39
41  -9.3287E-01   0.0000E-39   -1.4514E 01   -2.2843E 01   -0.0000E-39
```

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Output page 11

A

Print Symbol	Math Equation or Symbol	Definition
SIG(PHI)		Meridional stress, inner surface
SIG(THETA)	Equation 79, Section 1.4.3	Circumferential stress, inner surface
SG(PHI, THETA)		Shear stress, inner surface
SG2(PHI)		Meridional stress, chosen surface
SG2 (THETA)		Circumferential stress, chosen surface
SG2(PHI, THETA)		Shear stress, chosen surface

Pages 9, 10, 11 are repeated first for other regions and then for other thetas.

3.6 SAMPLE PROBLEM

To demonstrate the use of the computer program and illustrate the format for data input, the sample problem shown in Figure 3.6 has been worked out. This problem is a hypothetical one, selected to illustrate the use of many options in the program. The problem features an unsymmetrical load distribution, varying temperature loads, branch and eccentric discontinuity junctions, applied boundary forces, discontinuity loads, and others. The details for setting up this problem are described in the following paragraphs. Sample data sheets are presented in Section 3.4.9.

3.6.1 Problem Setup

The first step toward setting up this problem is a suitable selection of a mathematical model. For the shell configuration considered, it will be necessary to divide the shell into at least four regions for computer solution. Using four regions, it will be convenient to draw a line diagram of the geometry denoting the extent of each region, the junction, and appropriate end conditions. This line diagram is shown in Figure 3.7. The arrows indicate direction of increasing meridional coordinate or station numbers. The sequence of input of regional data is given by the numeral designation given the particular regions (i.e., 1-2-3-4). Other sequences for numbering regions are permissible provided the selection is consistent with solution

```
 I   SIG(PHI)     SIG(THETA)  SG(PHI,THETA)  SG2(PHI)     SG2(THETA)  SG2(PHI,THETA)

 1  -1.0177E 04  -1.0177E 04   0.0000E-39   1.0127E 04   1.0127E 04   0.0000E-39
 2  -1.0164E 04  -1.0172E 04  -0.0000E-39   1.0116E 04   1.0108E 04   0.0000E-39
 3  -1.0155E 04  -1.0159E 04  -0.0000E-39   1.0092E 04   1.0066E 04  -0.0000E-39
 4  -1.0146E 04  -1.0147E 04  -0.0000E-39   1.0069E 04   1.0028E 04  -0.0000E-39
 5  -1.0136E 04  -1.0134E 04  -0.0000E-39   1.0046E 04   9.9934E 03  -0.0000E-39
 6  -1.0125E 04  -1.0120E 04  -0.0000E-39   1.0023E 04   9.9599E 03  -0.0000E-39
 7  -1.0111E 04  -1.0103E 04  -0.0000E-39   9.9985E 03   9.9272E 03  -0.0000E-39
 8  -1.0096E 04  -1.0085E 04  -0.0000E-39   9.9732E 03   9.8948E 03  -0.0000E-39
 9  -1.0078E 04  -1.0065E 04  -0.0000E-39   9.9466E 03   9.8626E 03  -0.0000E-39
10  -1.0059E 04  -1.0043E 04  -0.0000E-39   9.9187E 03   9.8302E 03  -0.0000E-39
11  -1.0037E 04  -1.0020E 04  -0.0000E-39   9.8895E 03   9.7975E 03  -0.0000E-39
12  -1.0014E 04  -9.9957E 03  -0.0000E-39   9.8590E 03   9.7644E 03  -0.0000E-39
13  -9.9867E 03  -9.9699E 03  -0.0000E-39   9.8273E 03   9.7308E 03  -0.0000E-39
14  -9.9619E 03  -9.9431E 03  -0.0000E-39   9.7943E 03   9.6966E 03  -0.0000E-39
15  -9.9336E 03  -9.9152E 03  -0.0000E-39   9.7603E 03   9.6618E 03  -0.0000E-39
16  -9.9040E 03  -9.8865E 03  -0.0000E-39   9.7251E 03   9.6263E 03  -0.0000E-39
17  -9.8732E 03  -9.8571E 03  -0.0000E-39   9.6890E 03   9.5902E 03  -0.0000E-39
18  -9.8412E 03  -9.8270E 03  -0.0000E-39   9.6521E 03   9.5534E 03  -0.0000E-39
19  -9.8084E 03  -9.7963E 03  -0.0000E-39   9.6143E 03   9.5161E 03  -0.0000E-39
20  -9.7746E 03  -9.7651E 03  -0.0000E-39   9.5759E 03   9.4781E 03  -0.0000E-39
21  -9.7402E 03  -9.7335E 03  -0.0000E-39   9.5369E 03   9.4395E 03  -0.0000E-39
22  -9.7052E 03  -9.7015E 03  -0.0000E-39   9.4973E 03   9.4004E 03  -0.0000E-39
23  -9.6696E 03  -9.6692E 03  -0.0000E-39   9.4572E 03   9.3607E 03  -0.0000E-39
24  -9.6335E 03  -9.6366E 03  -0.0000E-39   9.4167E 03   9.3207E 03  -0.0000E-39
25  -9.5972E 03  -9.6038E 03  -0.0000E-39   9.3759E 03   9.2802E 03  -0.0000E-39
26  -9.5605E 03  -9.5708E 03  -0.0000E-39   9.3348E 03   9.2392E 03  -0.0000E-39
27  -9.5234E 03  -9.5375E 03  -0.0000E-39   9.2936E 03   9.1981E 03  -0.0000E-39
28  -9.4862E 03  -9.5041E 03  -0.0000E-39   9.2521E 03   9.1556E 03  -0.0000E-39
29  -9.4489E 03  -9.4706E 03  -0.0000E-39   9.2104E 03   9.1147E 03  -0.0000E-39
30  -9.4114E 03  -9.4369E 03  -0.0000E-39   9.1687E 03   9.0728E 03  -0.0000E-39
31  -9.3737E 03  -9.4031E 03  -0.0000E-39   9.1269E 03   9.0305E 03  -0.0000E-39
32  -9.3360E 03  -9.3692E 03  -0.0000E-39   9.0853E 03   8.9882E 03  -0.0000E-39
33  -9.2983E 03  -9.3352E 03  -0.0000E-39   9.0433E 03   8.9457E 03  -0.0000E-39
34  -9.2606E 03  -9.3011E 03  -0.0000E-39   9.0013E 03   8.9030E 03  -0.0000E-39
35  -9.2229E 03  -9.2669E 03  -0.0000E-39   8.9593E 03   8.8603E 03  -0.0000E-39
36  -9.1852E 03  -9.2326E 03  -0.0000E-39   8.9169E 03   8.8175E 03  -0.0000E-39
37  -9.1476E 03  -9.1982E 03  -0.0000E-39   8.8748E 03   8.7746E 03  -0.0000E-39
38  -9.1100E 03  -9.1638E 03  -0.0000E-39   8.8327E 03   8.7316E 03  -0.0000E-39
39  -9.0723E 03  -9.1292E 03  -0.0000E-39   8.7906E 03   8.6887E 03  -0.0000E-39
40  -9.0346E 03  -9.0945E 03  -0.0000E-39   8.7485E 03   8.6458E 03  -0.0000E-39
41  -8.9969E 03  -9.0597E 03  -0.0000E-39   8.7066E 03   8.6029E 03  -0.0000E-39
```

Output Page 11

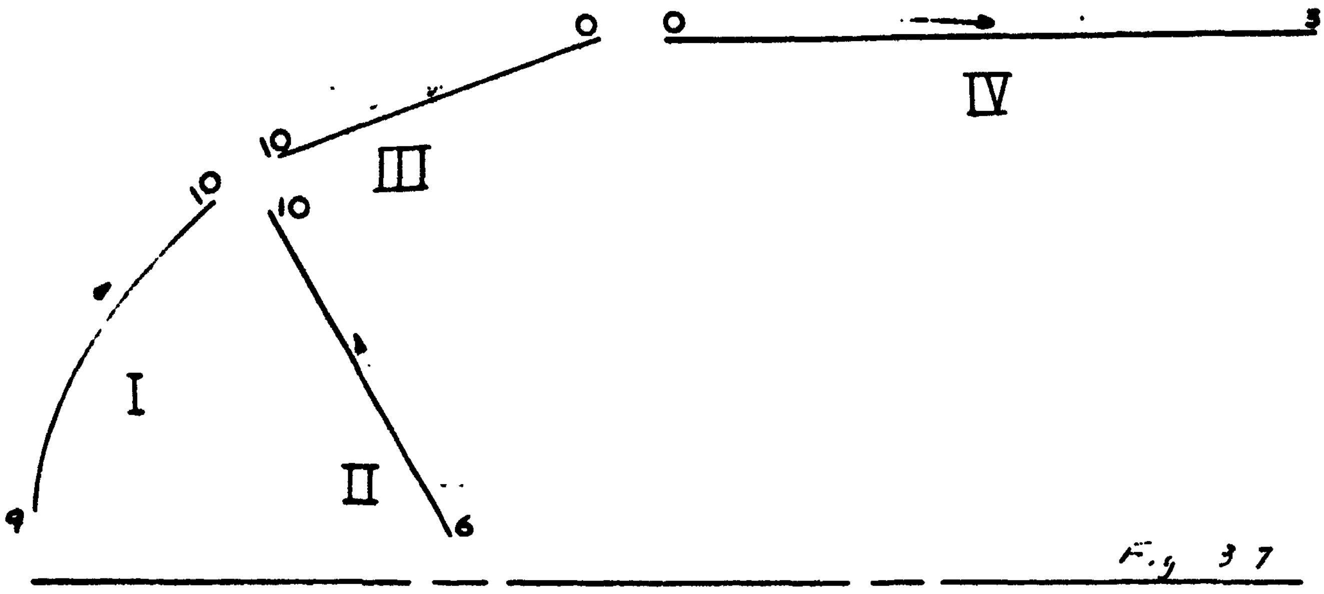

Figure 3.7

procedure of the program. Referring to the region numbering system shown in Figure 3.7, the problem could be consistently formulated by sequencing the regional input data (with appropriate end condition, of course) in these following combinations: (2-1-3-4), (4-3-2-1), and (4-3-1-2). The sequences (1-2-4-3) and (2-4-3-1) for example would not offer consistent formulation since a continuous transgression to the next region is not possible with this format. Using the example illustrated in Figure 3.6 let us now proceed to the input of regional data information.

3.6.2 Regional Data

Let us now consider the individual shell regions that make up the shell configuration (Figure 3.8 a-d).

Region I

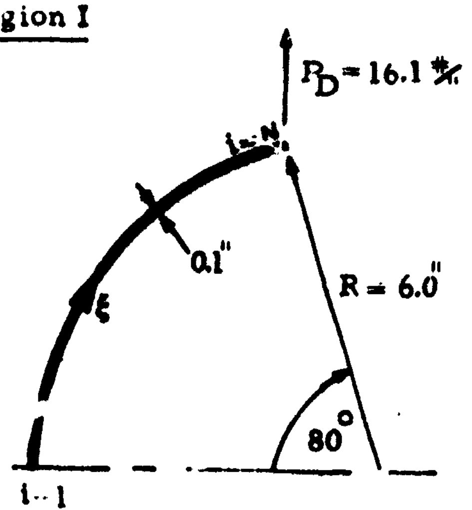

Figure 3.8a

Region I is a sperical shell with an opening angle of 80 degrees. The end condition at (i = 1) is a closed apex and requires that BCITP be set equal to 9. Since this region joins to two other shells at i = N, its bottom boundary (BCIBM) is set equal to 10.

The mechanical loading on the shell consists of an unsymmetric external normal pressure load with a distribution given in the form

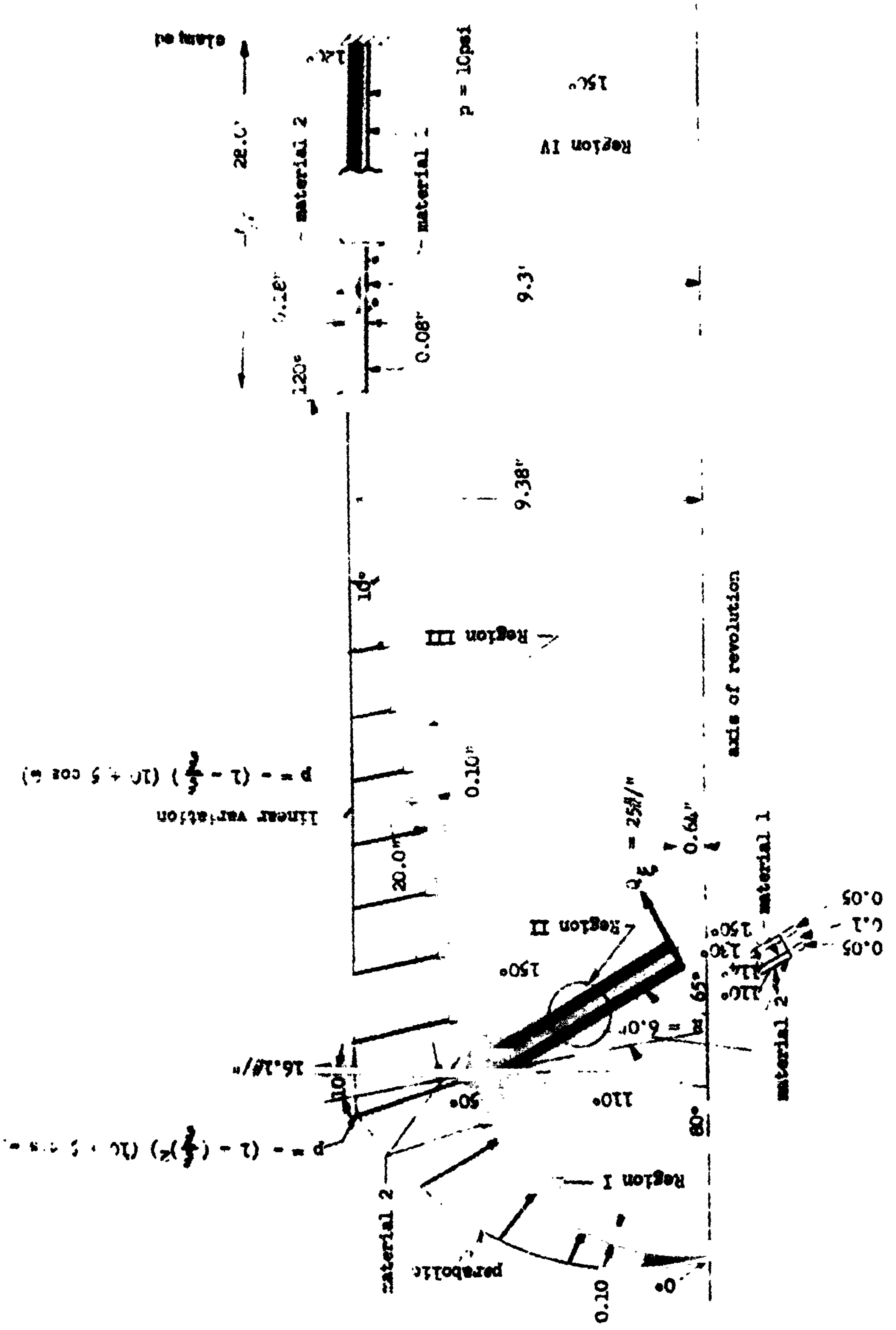
clamped
28.0"
material 2
material 1
140°
150°
p = 10psi
Region IV
0.08"
9.3"
120°
9.38"
10°
Region III
axis of revolution
$p = -(1 - \frac{\xi}{\ell})(10 + 5\cos\theta)$
linear variation
0.10"
20.0"
$Q_\xi = 25\#/"$
0.64"
material 1
Region II
150°
0.05
0.1
0.05
130°
114°
110°
material 2
R = 6.0"
65°
16.1#/"
10°
50°
110°
80°
$p = -(1 - (\frac{\xi}{\ell})^2)(10 + 5\cos\theta)$
material 2
Region I
parabolic
0.10
0°

Figure 3.6

$$p = -\left(1 - \left(\frac{\xi}{\bar{\xi}}\right)^2\right)(10 + 5\cos\theta)$$

where $\bar{\xi}$ is the arc length of the shell (dimensionless).

The form of this load requires that the problem be defined by two Fourier harmonics (n = 0, 1) in order to obtain complete solutions. The temperature applied to this region is a constant temperature differential of 110 degrees (0° reference) applied to the inner surface and linearly varying temperature at the outer surface starting from 0° at the apex to 50 degrees at station i = N. The number of stations considered in this region is 121. A line load of 16.1 pounds per inch is applied at the branch junction which requires values of $\psi = -10°$ and $P_D = 16.1$ in DLD (1005) and DLD (1006), respectively. If desired this load could be read in with data for region II. In this case, ψ would be set equal to 115 degrees.

REGION II

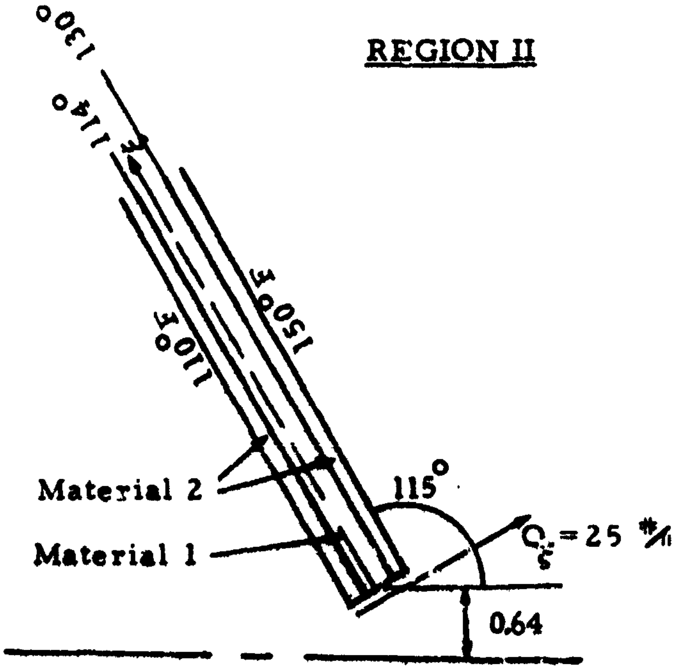

Figure 3.8b

Region II is a conical shell in which the cone angle input (ANX) is 115 degrees. This region is a three-layer section with constant temperature of 110 degrees at outer surface and 150 degrees at inner surface. The middle layer (0.1-inch thick) is constructed of material 2 and layers 1 and 3 (0.05-inch thick) are of material 1. The temperatures at the interfaces are shown in the accompanying figure and are reflected in the gradient table shown on card 143. A force-free end condition excepting for an applied axisymmetric shear load (25 pounds per inch) exists at top boundary (station 1). This boundary condition requires that BCITP be set equal to 6, and appropriate diagonal boundary arrays are read in EM1X, EM3X, EM5X array in GDA locations 620-632. The other endpoint corresponds to a branch junction and BCIBM is set equal to 10.

Region III

The third region is a single-layer conical shell. The end conditions are stipulated at i = 1 by setting BCITB = 10 since this is a branch point and BCIBM = 0 at i = N, a discontinuity point. The temperature of outer surface is assumed to vary linearly from 50 degrees at station 1 to 120 degrees at the last station. The inner surface has a constant temperature of 150 degrees.

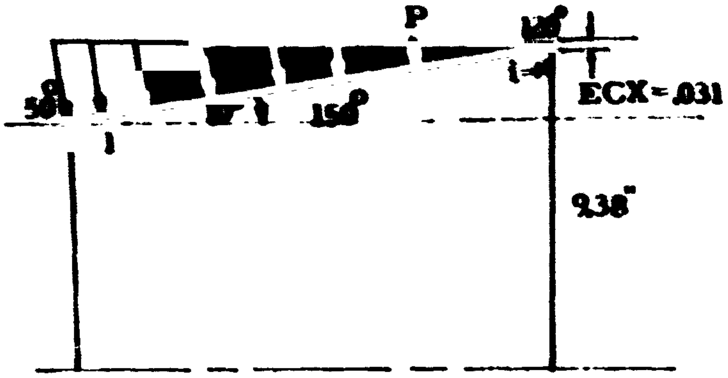

Figure 3. 8 c

The unsymmetrical pressure load has the distribution

$$p = -\left(1 - \frac{\xi}{\xi}\right)(10 + 5\cos\theta)$$

Material 1 is used and the number of stations have been chosen at 141.

Since an eccentricity in reference surface occurs between Regions III and IV, the eccentricity distance ECX is set equal to 0.031 and discontinuity angle $\smile$ = 10 degrees.

Region IV

The last region is a two-layer cylindrical shell. The boundary condition at the last station is assumed to be clamped, then BCIBM = 3.0. A uniform internal pressure of 10 psi acts on the section and temperatures of outer and inner surfaces and 120 degrees and 150 degrees, respectively. The outer layer is constructed of material 2 and the inner layer of material 1. The temperature gradient across the shell thickness is assumed to vary along the meridian of the shell. The values are shown on data sheets.

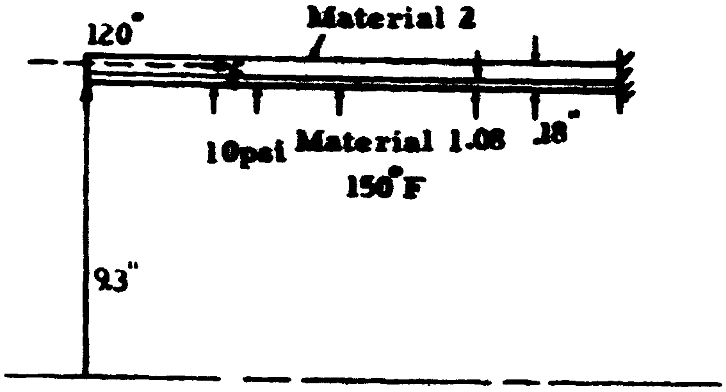

Figure 3. 8 d

3.6.3 Data Sheets and Results

The regional data for each region are written on standard IBM data sheets. The complete data for the sample problem are shown in the following IBM data form sheets.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO 1 PROGRAMMER S. Furuike DATE 8/22/66 PAGE 1 OF 22 JOB NO 2733-01

NUMBER

```
BRANCHED SHE
LL SAMPLE PR
ØBLEM FØR US
ERS MANUAL *
* AUGUST 19,
1966                    1
FØUR REGIØNS
* SPHERE -
CØNE - CØNE
- CYLINDER *
UNSYMMETRIC
AL PRESSURE             2
LØADING, TEM
PERATURE LØA
DS, LAYERED
REGIØNS, BØU
NDARY FØRCE
                        3
```

Three Title Cards Ⓐ

See Section 3.4.4

Ⓑ

Ⓐ Three cards are necessary, but they may be blank if desired.

Ⓑ Identification numbers are safeguards against data deck "scrambling". E.g., a card of GDA data preceding the last (-) card of the DA data, will be read into the DA array. The actual values are optional but should be chosen to permit additions and sorting of entire deck.

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Sample Data Sheet

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER DATE PAGE 2 OF 22 JOB NO 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1		DA (General Data)
13	4.		EKK See Section 3.4.4
25	1.		A0
37	1.		H0
49	1.	73 80	E0
61	1.	10	SIG0
1	6		
13	1.		PIXI
25			PTHI Ⓑ
37	1.		SUM
49		73 80	ENF0 Ⓑ
61	1.	11	ENFI (1)
1	Ⓐ 21		
13	0.		ENFΦR (1) Ⓒ
25	1.		(2)
37			
49		73 80	
61	0.	12	THETA (1)

Ⓐ This is the last card of the DA data array

Ⓑ PTHI & ENFO are zero so do not have to be entered for a first case

Ⓒ Prints are wanted for both Fourier components, 0. and 1. It is necessary to enter the zero for ENFΦR (1) because DA is filled with a data flag from ENFI (1) through the THETA values.

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

3 22 JOB NO. 2733-01

NUMBER	LOCATION	DESCRIPTION	NOTES
1			**GDA (Geometry Data)**
2.		**GMI**	**Region 1**
121.		**EN**	**See Section 3. 4. 5**
-1.		**PFLAG**	
9.		**BCITP**	
10. Ⓐ	20	**BCIBM**	Ⓐ **Branched Shell (Sec. 1. 4. 5)**
15 Ⓑ			Ⓑ **GDA (6) through GDA (14) do not apply to**
6.05		**RC**	***this case & have been set to zero by***
		RΦFF	**the program.**
Ⓒ		**PHI0**	Ⓒ **Automatic zeroes**
80.		**PHIN**	
	21		
1			**SDA (Special Data)**
0. Ⓓ		**EX**	**Region 1**
			See Section 3. 4. 6
			Ⓓ **Data cards for DLD and DAL**
			must follow.
	30		
1			**DLD (Loads Data)**
2.		**PILD**	**Region 1**
1.		**TIBT**	**See Section 3. 4. 7**
2.		**TITP**	
	40		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO PROGRAMMER DATE PAGE 4 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
405		DLD, cont. - Region 1
2.		PNTB - No. of ENF's
0.		1st ENF
4.		No. of stations
1. Ⓐ		Station No. = 1. Ⓐ First station must be 1.
0.	41	Load at station 1.
605	Ⓑ	Ⓑ Cards are inserted at this
110.		TBΦT point by using intermediate
		sequence no. and having the
		deck sorted. Inserts are
		found on pages 7, 8, and 9.
	45	
805		
2.		TTΦP
0.		1st ENF
2.		No. of stations
1. Ⓐ		First Station
0.	46	Temp. at station 1.
1	Ⓑ	DAL (Section Properties)
1.		ELAY Region 1
1.		STRIX See Section 3. 4. 8
1.		EIFH
	50	

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO | PROGRAMMER | DATE | PAGE 5 of 22 | JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
25			DAL, cont. - Region 1
.1		TH	
			Ⓐ Although region 1 does not use
			material 1, the materials properties
	51		tables for all materials, DAL (158)
145			through DAL (283), must be entered
2.		ENMAT	with the first region which contains
2.	Ⓐ	EMAT (1)	DAL data and the value for ENMAT
			is the number of materials in these
			tables.
	52		
152			
.3		PØIS (1)	
	53		
158			
4.	Ⓐ	ENE1 (First material)	
-1000.		TMPE1 (1)	
0.		TMPE1 (2)	
100.		TMPE1 (3)	
1000.	60	TMPE1 (4)	

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO PROGRAMMER DATE PAGE 6 of 22 JOB NO. 2733-01

NUMBER		IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
169				DAL, cont. - Region 1
6.5	+6		YM1 (1)	
6.5	+6		YM1 (2)	
6.5	+6		YM1 (3)	
6.0	+6		YM1 (4)	
		61		
179				
2.			ENE2	(Second Material)
-1000.			TMPE2 (1)	
1000.			(2)	
				Ⓐ DAL (158) through DAL (284),
		70		the tables of temperature vs.
190				Young's Modulus & the Coef. of
1.	+7		YM2 (1)	thermal Expansion for the 3
1.	+7		(2)	materials, are preserved and
				used for all regions and Fourier
				components. Therefore, the
		71		given temperature range should
221				bracket all expected temperatures.
3.			ENA1	
-1000.			TMPA1 (1)	
1000.			(2)	
1500.			(3)	
		80		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 7 OF 22 JOB NO. 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	2 3 2		DAL, cont. - Region 1
13	1 . 4 - 5		ALF1 (1)
25	1 . 3 - 5		(2)
37	1 . 2 - 5		(3)
49			
61		8 1	
1	2 4 2		
13	2 .		ENA2
25	- 1 0 0 0 .		TMPA2 (1)
37	1 0 0 0 .		
49			
61		9 0	
1	2 5 3		
13	1 . 3 3 - 5		ALF2 (1)
25	1 . 3 3 - 5		(2)
37			
49			
61		9 1	
1	4 1 C		
13	5 8 .		2nd sta.
25	- 7 . 5 Ⓑ		load
37	8 8 .		3rd sta.
49	- 9 . 1 9 Ⓑ	Ⓐ	load
61	1 2 1 .	4 2	4th sta.

Ⓐ Insert for pg. 4

Ⓑ This load will be multiplied by A0/ (SIG0 * H0) before curve fitting to all stations.

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Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 8 of 22 JOB NO 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
1	415			DLD, cont. - Region 1
13	-10.		load	Ⓐ Inserts for pg. 4
25	1.		2nd ENF	
37	4.		No. of sta.	
49	1.	73 Ⓐ 80	1st sta.	
61	0.	43	1st val.	
1	420			
13	58.		2nd sta.	
25	-3.75		2nd val.	
37	88.		3rd sta.	
49	-4.595	73 Ⓐ 80	3rd val.	
61	121.	44	4th sta.	
1	425			
13	-5.		4th val.	
25				
37				
49		73 Ⓐ 80		
61		45		
1	810			
13	121.		2nd station	
25	50.		Temp. at 2nd station	
37	1.		2nd ENF	
49	2.	73 Ⓐ 80	No. of stations	
	1.	47	1st station	

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Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER 9 22 2733-04

	NUMBER	IDENTIFICATION	DESCRIPTION	
1	615			DLD. Cont. - Region 1
13	0.		Temp. at station 1	Ⓐ Inserts for Pg. 4
25	121.		2nd station	
37	0.		Temp. at station 2	
49		73 Ⓐ 80		
61		48		
1	- 1005			
13	-10.		Angle at which load is applied at lower boundary	
25	16.1		Initial Fourier component of load applied at lower boundary	
37				
49		73 Ⓐ		
61		49		
1				
13				
25				
37				
49		73 80		
61				
1				
13				
25				
37				
49		73 80		
61				

FORM 114-C-17 REV. 7-58

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER DATE PAGE 10 of 22 JOB NO. 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
1	1			GDA (Geometry Data)
13	1.		GMI	Region 2
25	109.		EN	
37	1.		PFLAG	
49	6.		BCITP	
61	10.	100	BCIBM	Ⓐ Cards are inserted at this
1	-15	Ⓐ		by using intermediate sequence
3	.64081071		RA1	No. and having the deck sorted.
25	5.8669875		AXL	Inserts are found on Page 13.
37	115.		ANX	
49				
61		109		
1	-1			SDA (Special Data)
13	0.		EX	Region 2
25				
37				
49				
61		110		
1	1			DLD (Loads Data)
3	1.		PILD	Region 2
25	1.		TIBT	
	1.		TITB	
		120		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO PROGRAMMER DATE 11 22 2733-01

NUMBER

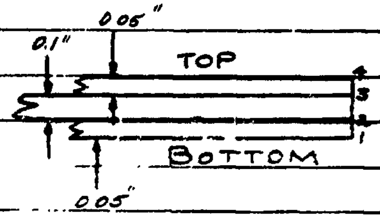
605			DLD, cont. - Region 2
150.		TBØT	
	121		
805			
110.		TTØP	
	122		
1			DAL (Section Properties)
3.		ELAY	Region 2
3.		STRIX	
1.		EIFH	
	130		
25			
.05		TH (1st layer)	
.1		(2nd layer)	
.05		(3rd layer)	
	131		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER DATE PAGE 12 of 22 JOB NO. 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	145		DAL, cont. - Region 2
13	2.		ENMAT
25	2.		EMAT (1st layer)
37	1.		(2nd layer)
49	2.		(3rd layer)
61		140	
1	152		
13	.3		PΦIS (1)
25	.35		(2)
37	.3		(3)
49			
61		141	
1	284		
13	1.		ENΦGR (constants)
25			
37			
49			
61		142	
1	295		
13	.5		GR (interface 2)
25	.9		(interface 3)
37			
49			
61		143	



Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO PROGRAMMER DATE PAGE 13 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
620			Inserts for pg. 10
1.		EX1X (1)	
1.		(2)	
1.		(3)	
0.		(4)	
0.	101	EM3X (1)	
625			
0.		(2)	
0.		(3)	
1.		(4)	
0.		EM5X (1) (1st ENF)	
0.	102	(2)	
630			
25.		(3)	
0.		(4)	
		EM5X (2nd ENF)	
	103		
6			
105.		GPSI, Discontinuity angle of lower boundary	
	104		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. – PROGRAMMER DATE – PAGE 14 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
1			GDA (Geometry Data)
1.		GMI	Region 3
121.		EN	
1.		PFLAG	
10.		BCITP	
	200		
6			
10.		GPSI	
-.031		GECX	
	201		
15			
5.958086		RAI	
20.		AXL	
10.		ANX	
	202		
1			SDA (Special Data)
0.		EX	Region 3
	210		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 15 of 22 JOB NO. 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH	
1	1			DLD (Loads Data)
13	2.		PILD	Region 3
25	1.		TIF	
37	2.		TITP	
49				
61		220		
1	405			
13	2.		PNTB	
25	0.		1st ENF	
37	2.			
49	1.			
61	-10.	221		
1	410			
13	121.			
25	0.			
37	1.		2nd ENF	
49	2.			
61	1.	222		
1	415			
13	-5.			
25	121.			
37	0.			
49				
61		223		

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER DATE PAGE 16 of 22 JOB NO 2733-01

DLD, cont. - Region 3

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	605		
13	150.		TBΦT
25			
37			
49		73 80	
61		230	
1	805		
13	2.		TTΦP
25	0.		1st ENF
37	2.		
49	1.	73 80	
61	50.	231	
1	810		
13	121.		
25	120.		
37	1.		2nd ENF
49	2.	73 80	
61	1.	232	
1	- 815		
13	0.		
25	121.		
37	0.		
49		73 80	
61		233	

FORM 114-C-17 REV. 7-58

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER DATE 17 . 22 JOB NO 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH	
1	1			DAL (Section Properties)
13	1.		ELAY	R[illegible]on 3
25	1.		STRIX	
37	1.		EIFH	
49				
61		73 … 80 240		
1	25			
13	.1		TH	
25				
37				
49				
61		73 … 80 241		
1	145			
13	2.		ENMAT	
25	2.		EMAT	
37				
49				
61		73 … 80 242		
1	152			
13	.3		PΦIS (1)	
25				
37				
49				
61		73 … 80 243		

FORM 114-C-17 REV. 7-58

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 18 of 22 JOB NO. 2733-01

	NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
1	1			GDA (Geometry Data)
13	1.		GMI	Region 4
25	113.		EN	
37	1.		PFLAG	
49		73 80		
61	3.	300	BCIBM	
1	-15			
13	9.40		RA1	
25	28.		AXL	
37	0.		ANX	
49		73 80		
61		301		
1	-1			SDA (Special Data)
13	0.		EX	Region 4
25				
37				
49		73 80		
61		310		
1	1			DLD (Loads Data)
13	1.		PILD	Region 4
25	1.		TIBT	
37	1.		TITP	
49				
61		320		

ORM 114-C-17 REV. 7-58

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. PROGRAMMER DATE PAGE 19 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
4 0 5			DLD, cont. - Region 4
1 0 .		PNTB	
	3 3 0		
6 0 5			
1 5 0 .		TBΦT	
	3 3 1		
8 0 5			
1 2 0 .		TTΦP	
	3 3 2		
1			DAL (Section Properties)
2 .		ELAY	Region 4
2 .		STRIX	
- 1 .		EIFH	
6 .		ENΦTH	
1 .	3 4 0	THSTA (1)	

DPM 114-C-17 REV 7-58

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 20 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
6		DAL, cont. - Region 4
19.		THSTA (2)
45.		(3)
67.		(4)
91.	73 80	(5)
113.	341	(6)
25		
.08		TH (1, 1)
.079		(2, 1)
.078		(3, 1)
.075	73 80	(4, 1)
.071	345	(5, 1)
30		
.068		TH (6, 1)
	73 80	
	346	
45		
.1		TH (1, 2)
.1		(2, 2)
.1		(3, 2)
.1	73 80	(4, 2)
.1	350	(5, 2)

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 21 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
50		DAL, cont. - Region 4
.1		TH (6, 2)
	351	
145		
2.		ENMAT
1.		EMAT (1)
2.		EMAT (2)
	360	
152		
.35		PΦIS (1)
.3		(2)
	361	
284		
4.		ENΦGR
1.		GSTA (1)
67.		(2)
91.		(3)
113.	370	(4)

Sample Data Sheet (Cont)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ____ PROGRAMMER ____ DATE ____ PAGE 22 of 22 JOB NO. 2733-01

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
- 2.9.5		DAL, cont. - Region 4
.8		GR (1, 1)
. 7 3		(2, 1)
. 6 2		(3, 1)
. 5 8	73 80	(4, 1)
	3 7 1	

FORM 114-C-17 REV. 7-58

Sample Data Sheet (Cont)

```
REGION  3, DEFLECTIONS AND INTERNAL LOADS, THETA =  9.0000E 01   ENF =  1.0000E 00

  I      U(I)          V(I)          W(I)          M(PHI)        M(THETA)     M(PHI,THETA)

  1  -7.3832E-02   1.4706E-02   2.1720E-02   3.0164E 01   2.0049E 01    6.8557E-04
  2  -7.3623E-02   1.4645E-02   2.2077E-02   2.5199E 01   1.8548E 01   -7.1989E-03
  3  -7.3414E-02   1.4584E-02   2.2147E-02   2.1240E 01   1.7328E 01   -1.1521E-02
  4  -7.3205E-02   1.4523E-02   2.2047E-02   1.8298E 01   1.6399E 01   -1.2486E-02
  5  -7.2993E-02   1.4461E-02   2.1864E-02   1.6264E 01   1.5732E 01   -1.1444E-02
  6  -7.2778E-02   1.4399E-02   2.1657E-02   1.4970E 01   1.5280E 01   -9.3868E-03
  7  -7.2562E-02   1.4337E-02   2.1462E-02   1.4234E 01   1.4991E 01   -6.9891E-03
  8  -7.2342E-02   1.4275E-02   2.1299E-02   1.3890E 01   1.4818E 01   -4.6709E-03
  9  -7.2121E-02   1.4213E-02   2.1176E-02   1.3798E 01   1.4720E 01   -2.6597E-03
 10  -7.1898E-02   1.4150E-02   2.1093E-02   1.3851E 01   1.4666E 01   -1.0487E-03
 11  -7.1674E-02   1.4087E-02   2.1044E-02   1.3970E 01   1.4633E 01    1.5463E-04
 12  -7.1448E-02   1.4024E-02   2.1024E-02   1.4104E 01   1.4605E 01    9.9282E-04
 13  -7.1222E-02   1.3961E-02   2.1026E-02   1.4220E 01   1.4572E 01    1.5312E-03
 14  -7.0995E-02   1.3897E-02   2.1043E-02   1.4303E 01   1.4531E 01    1.8402E-03
 15  -7.0768E-02   1.3833E-02   2.1069E-02   1.4348E 01   1.4479E 01    1.9861E-03
 16  -7.0539E-02   1.3769E-02   2.1102E-02   1.4356E 01   1.4416E 01    2.0245E-03
 17  -7.0311E-02   1.3705E-02   2.1138E-02   1.4330E 01   1.4343E 01    1.9993E-03
 18  -7.0081E-02   1.3640E-02   2.1174E-02   1.4279E 01   1.4263E 01    1.9423E-03
 19  -6.9852E-02   1.3575E-02   2.1209E-02   1.4208E 01   1.4177E 01    1.8754E-03
 20  -6.9621E-02   1.3510E-02   2.1244E-02   1.4124E 01   1.4088E 01    1.8119E-03
 21  -6.9390E-02   1.3445E-02   2.1277E-02   1.4030E 01   1.3995E 01    1.7591E-03
 22  -6.9159E-02   1.3379E-02   2.1308E-02   1.3932E 01   1.3901E 01    1.7198E-03
 23  -6.8927E-02   1.3314E-02   2.1339E-02   1.3831E 01   1.3806E 01    1.6942E-03
 24  -6.8694E-02   1.3248E-02   2.1368E-02   1.3730E 01   1.3712E 01    1.6810E-03
 25  -6.8461E-02   1.3182E-02   2.1397E-02   1.3630E 01   1.3617E 01    1.6780E-03
 26  -6.8227E-02   1.3116E-02   2.1426E-02   1.3533E 01   1.3522E 01    1.6827E-03
 27  -6.7992E-02   1.3049E-02   2.1454E-02   1.3433E 01   1.3429E 01    1.6929E-03
 28  -6.7757E-02   1.2983E-02   2.1482E-02   1.3336E 01   1.3335E 01    1.7065E-03
 29  -6.7521E-02   1.2916E-02   2.1510E-02   1.3241E 01   1.3242E 01    1.7219E-03
 30  -6.7285E-02   1.2849E-02   2.1539E-02   1.3147E 01   1.3149E 01    1.7381E-03
 31  -6.7048E-02   1.2783E-02   2.1567E-02   1.3054E 01   1.3056E 01    1.7543E-03
 32  -6.6810E-02   1.2715E-02   2.1596E-02   1.2961E 01   1.2964E 01    1.7699E-03
 33  -6.6572E-02   1.2648E-02   2.1625E-02   1.2869E 01   1.2871E 01    1.7848E-03
 34  -6.6333E-02   1.2581E-02   2.1654E-02   1.2777E 01   1.2779E 01    1.7989E-03
 35  -6.6094E-02   1.2513E-02   2.1684E-02   1.2685E 01   1.2687E 01    1.8120E-03
 36  -6.5854E-02   1.2446E-02   2.1713E-02   1.2593E 01   1.2595E 01    1.8242E-03
 37  -6.5613E-02   1.2378E-02   2.1743E-02   1.2501E 01   1.2502E 01    1.8355E-03
 38  -6.5372E-02   1.2310E-02   2.1773E-02   1.2409E 01   1.2410E 01    1.8462E-03
```

Sample Problem Output

```
 39  -6.5130E-02   1.2242E-02   2.1804E-02   1.2316E 01   1.2318E 01   1.8564E-03
 40  -6.4887E-02   1.2174E-02   2.1834E-02   1.2224E 01   1.2225E 01   1.8661E-03
 41  -6.4644E-02   1.2106E-02   2.1865E-02   1.2132E 01   1.2133E 01   1.8751E-03
 42  -6.4400E-02   1.2037E-02   2.1896E-02   1.2040E 01   1.2041E 01   1.8838E-03
 43  -6.4'56E-02   1.1969E-02   2.1927E-02   1.1947E 01   1.1948E 01   1.8923E-03
 44  -6.3911E-02   1.1901E-02   2.1958E-02   1.1855E 01   1.1856E 01   1.9004E-03
 45  -6.3665E-02   1.1832E-02   2.1989E-02   1.1763E 01   1.1764E 01   1.9081E-03
 46  -6.3419E-02   1.1764E-02   2.2021E-02   1.1670E 01   1.1671E 01   1.9157E-03
 47  -6.3172E-02   1.1695E-02   2.2052E-02   1.1578E 01   1.1579E 01   1.9229E-03
 48  -6.2924E-02   1.1626E-02   2.2084E-02   1.1485E 01   1.1486E 01   1.9299E-03
 49  -6.2676E-02   1.1557E-02   2.2116E-02   1.1393E 01   1.1394E 01   1.9366E-03
 50  -6.2428E-02   1.1489E-02   2.2149E-02   1.1301E 01   1.1302E 01   1.9431E-03
 51  -6.2178E-02   1.1420E-02   2.2181E-02   1.1208E 01   1.1209E 01   1.9493E-03
 52  -6.1928E-02   1.1351E-02   2.2214E-02   1.1116E 01   1.1117E 01   1.9551E-03
 53  -6.1678E-02   1.1282E-02   2.2246E-02   1.1023E 01   1.1025E 01   1.9608E-03
 54  -6.1427E-02   1.1213E-02   2.2279E-02   1.0931E 01   1.0932E 01   1.9663E-03
 55  -6.1175E-02   1.1144E-02   2.2312E-02   1.0839E 01   1.0840E 01   1.9715E-03
 56  -6.0922E-02   1.1075E-02   2.2346E-02   1.0746E 01   1.0747E 01   1.9765E-03
 57  -6.0669E-02   1.1006E-02   2.2379E-02   1.0654E 01   1.0655E 01   1.9814E-03
 58  -6.0416E-02   1.0937E-02   2.2413E-02   1.0562E 01   1.0563E 01   1.9860E-03
 59  -6.0161E-02   1.0868E-02   2.2447E-02   1.0469E 01   1.0470E 01   1.9904E-03
 60  -5.9906E-02   1.0799E-02   2.2481E-02   1.0377E 01   1.0378E 01   1.9946E-03
 61  -5.9651E-02   1.0730E-02   2.2515E-02   1.0284E 01   1.0286E 01   1.9986E-03
 62  -5.9395E-02   1.0661E-02   2.2549E-02   1.0192E 01   1.0193E 01   2.0024E-03
 63  -5.9138E-02   1.0592E-02   2.2584E-02   1.0100E 01   1.0101E 01   2.0060E-03
 64  -5.8881E-02   1.0523E-02   2.2619E-02   1.0007E 01   1.0009E 01   2.0094E-03
 65  -5.8623E-02   1.0454E-02   2.2654E-02   9.9150E 00   9.9162E 00   2.0126E-03
 66  -5.8364E-02   1.0385E-02   2.2689E-02   9.8226E 00   9.8238E 00   2.0159E-03
 67  -5.8105E-02   1.0316E-02   2.2724E-02   9.7303E 00   9.7314E 00   2.0191E-03
 68  -5.7845E-02   1.0247E-02   2.2759E-02   9.6379E 00   9.6390E 00   2.0221E-03
 69  -5.7584E-02   1.0178E-02   2.2795E-02   9.5455E 00   9.5467E 00   2.0250E-03
 70  -5.7323E-02   1.0109E-02   2.2831E-02   9.4531E 00   9.4543E 00   2.0280E-03
 71  -5.7062E-02   1.0040E-02   2.2867E-02   9.3607E 00   9.3619E 00   2.0308E-03
 72  -5.6799E-02   9.9715E-03   2.2903E-02   9.2683E 00   9.2696E 00   2.0333E-03
 73  -5.6536E-02   9.9028E-03   2.2940E-02   9.1760E 00   9.1772E 00   2.0359E-03
 74  -5.6273E-02   9.8342E-03   2.2976E-02   9.0835E 00   9.0848E 00   2.0380E-03
 75  -5.6009E-02   9.7656E-03   2.3013E-02   8.9911E 00   8.9924E 00   2.0396E-03
 76  -5.5744E-02   9.6971E-03   2.3050E-02   8.8986E 00   8.9000E 00   2.0409E-03
 77  -5.5478E-02   9.6287E-03   2.3087E-02   8.8061E 00   8.8076E 00   2.0416E-03
 78  -5.5212E-02   9.5604E-03   2.3124E-02   8.7135E 00   8.7152E 00   2.0417E-03
 79  -5.4946E-02   9.4921E-03   2.3162E-02   8.6209E 00   8.6227E 00   2.0408E-03
 80  -5.4678E-02   9.4239E-03   2.3200E-02   8.5283E 00   8.5302E 00   2.0387E-03
 81  -5.4410E-02   9.3558E-03   2.3238E-02   8.4356E 00   8.4378E 00   2.0353E-03
```

Sample Problem Output (Cont)

```
 82  -5.4142E-02   9.2878E-03   2.3276E-02   8.3429E 00   8.3453E 00   2.0305E-03
 83  -5.3873E-02   9.2199E-03   2.3314E-02   8.2503E 00   8.2529E 00   2.0243E-03
 84  -5.3603E-02   9.1521E-03   2.3353E-02   8.1579E 00   8.1605E 00   2.0173E-03
 85  -5.3333E-02   9.0844E-03   2.3392E-02   8.0656E 00   8.0681E 00   2.0095E-03
 86  -5.3062E-02   9.0168E-03   2.3431E-02   7.9736E 00   7.9759E 00   2.0019E-03
 87  -5.2790E-02   8.9493E-03   2.3471E-02   7.8821E 00   7.8838E 00   1.9956E-03
 88  -5.2518E-02   8.8820E-03   2.3510E-02   7.7911E 00   7.7918E 00   1.9923E-03
 89  -5.2245E-02   8.8147E-03   2.3550E-02   7.7008E 00   7.7001E 00   1.9944E-03
 90  -5.1971E-02   8.7476E-03   2.3590E-02   7.6113E 00   7.6086E 00   2.0049E-03
 91  -5.1697E-02   8.6806E-03   2.3630E-02   7.5228E 00   7.5174E 00   2.0270E-03
 92  -5.1423E-02   8.6137E-03   2.3670E-02   7.4351E 00   7.4265E 00   2.0[illegible]7E-03
 93  -5.1147E-02   8.5470E-03   2.3709E-02   7.3484E 00   7.3358E 00   2.1219E-03
 94  -5.0871E-02   8.4804E-03   2.3749E-02   7.2622E 00   7.2454E 00   2.2026E-03
 95  -5.0595E-02   8.4140E-03   2.3787E-02   7.1762E 00   7.1550E 00   2.3097E-03
 96  -5.0317E-02   8.3477E-03   2.3825E-02   7.0897E 00   7.0645E 00   2.4445E-03
 97  -5.0039E-02   8.2815E-03   2.3862E-02   7.0015E 00   6.9735E 00   2.6054E-03
 98  -4.9761E-02   8.2155E-03   2.3898E-02   6.9102E 00   6.8816E 00   2.7871E-03
 99  -4.9482E-02   8.1496E-03   2.3932E-02   6.8140E 00   6.7882E 00   2.9782E-03
100  -4.9202E-02   8.0840E-03   2.3966E-02   6.7105E 00   6.6926E 00   3.1598E-03
101  -4.8921E-02   8.0184E-03   2.3999E-02   6.5971E 00   6.5940E 00   3.3042E-03
102  -4.8640E-02   7.9531E-03   2.4032E-02   6.4708E 00   6.4914E 00   3.3725E-03
103  -4.8358E-02   7.8880E-03   2.4066E-02   6.3288E 00   6.3840E 00   3.3138E-03
104  -4.8076E-02   7.8230E-03   2.4102E-02   6.1683E 00   6.2708E 00   3.0649E-03
105  -4.7793E-02   7.7582E-03   2.4143E-02   5.9876E 00   6.1514E 00   2.5511E-03
106  -4.7509E-02   7.6936E-03   2.4191E-02   5.7864E 00   6.0255E 00   1.6685E-03
107  -4.7225E-02   7.6292E-03   2.4250E-02   5.5666E 00   5.8938E 00   3.8989E-04
108  -4.6940E-02   7.5651E-03   2.4323E-02   5.3338E 00   5.7577E 00  -1.4265E-03
109  -4.6654E-02   7.5011E-03   2.4415E-02   5.0977E 00   5.6203E 00  -3.8253E-03
110  -4.6369E-02   7.4373E-03   2.4530E-02   4.8742E 00   5.4862E 00  -6.8361E-03
111  -4.6083E-02   7.3737E-03   2.4671E-02   4.6862E 00   5.3625E 00  -1.0431E-02
112  -4.5798E-02   7.3103E-03   2.4843E-02   4.5646E 00   5.2586E 00  -1.4498E-02
113  -4.5512E-02   7.2470E-03   2.5045E-02   4.5495E 00   5.1866E 00  -1.8809E-02
114  -4.5227E-02   7.1839E-03   2.5275E-02   4.6897E 00   5.1618E 00  -2.2980E-02
115  -4.4942E-02   7.1208E-03   2.5527E-02   5.0423E 00   5.2016E 00  -2.6443E-02
116  -4.4657E-02   7.0578E-03   2.5786E-02   5.6698E 00   5.3256E 00  -2.8401E-02
117  -4.4373E-02   6.9947E-03   2.6032E-02   6.6360E 00   5.5537E 00  -2.7810E-02
118  -4.4089E-02   6.9316E-03   2.6231E-02   7.9994E 00   5.9045E 00  -2.3361E-02
119  -4.3805E-02   6.8684E-03   2.6339E-02   9.8031E 00   6.3920E 00  -1.3495E-02
120  -4.3520E-02   6.8051E-03   2.6300E-02   1.2062E 01   7.0219E 00   3.5494E-03
121  -4.3234E-02   6.7416E-03   2.6043E-02   1.4745E 01   7.7863E 00   2.7146E-02
```

Sample Problem Output (Cont)

```
  I     Q(PHI)        Q(THETA)        N(PHI)        N(THETA)     N(PHI,THETA)

  1  -3.1807E 01   -8.9213E-02   -3.4269E 01    9.8061E 01   -1.6766E 01
  2  -2.6578E 01   -5.3437E-02   -3.5552E 01    1.5159E 02   -1.6885E 01
  3  -2.0590E 01   -2.2495E-02   -3.6262E 01    1.5769E 02   -1.7061E 01
  4  -1.4872E 01    2.6905E-04   -3.6585E 01    1.3622E 02   -1.7323E 01
  5  -9.9711E 00    1.3259E-02   -3.6669E 01    1.0159E 02   -1.7677E 01
  6  -6.1010E 00    1.9244E-02   -3.6609E 01    6.3505E 01   -1.8111E 01
  7  -3.2611E 00    2.0592E-02   -3.6497E 01    2.7831E 01   -1.8609E 01
  8  -1.3321E 00    1.9171E-02   -3.6388E 01   -2.3687E 00   -1.9155E 01
  9  -1.4156E-01    1.6348E-02   -3.6306E 01   -2.5982E 01   -1.9731E 01
 10   4.9312E-01    1.3054E-02   -3.6256E 01   -4.3124E 01   -2.0322E 01
 11   7.3900E-01    9.8683E-03   -3.6241E 01   -5.4599E 01   -2.0919E 01
 12   7.3521E-01    7.1043E-03   -3.6272E 01   -6.1508E 01   -2.1512E 01
 13   5.8915E-01    4.8892E-03   -3.6338E 01   -6.4992E 01   -2.2095E 01
 14   3.7806E-01    3.2338E-03   -3.6424E 01   -6.6086E 01   -2.2666E 01
 15   1.5321E-01    2.0821E-03   -3.6527E 01   -6.5651E 01   -2.3224E 01
 16  -5.4518E-02    1.3439E-03   -3.6638E 01   -6.4349E 01   -2.3768E 01
 17  -2.2939E-01    9.2207E-04   -3.6755E 01   -6.2659E 01   -2.4297E 01
 18  -3.6610E-01    7.2629E-04   -3.6869E 01   -6.0893E 01   -2.4811E 01
 19  -4.6576E-01    6.7992E-04   -3.6982E 01   -5.9245E 01   -2.5313E 01
 20  -5.3315E-01    7.2200E-04   -3.7100E 01   -5.7811E 01   -2.5802E 01
 21  -5.7459E-01    8.0853E-04   -3.7208E 01   -5.6619E 01   -2.6279E 01
 22  -5.9649E-01    9.0920E-04   -3.7304E 01   -5.5660E 01   -2.6745E 01
 23  -6.0468E-01    1.0059E-03   -3.7406E 01   -5.4908E 01   -2.7201E 01
 24  -6.0407E-01    1.0893E-03   -3.7505E 01   -5.4320E 01   -2.7647E 01
 25  -5.9842E-01    1.1535E-03   -3.7597E 01   -5.3852E 01   -2.8082E 01
 26  -5.9043E-01    1.1981E-03   -3.7697E 01   -5.3472E 01   -2.8508E 01
 27  -5.8197E-01    1.2252E-03   -3.7789E 01   -5.3143E 01   -2.8925E 01
 28  -5.7409E-01    1.2373E-03   -3.7870E 01   -5.2839E 01   -2.9332E 01
 29  -5.6737E-01    1.2382E-03   -3.7951E 01   -5.2547E 01   -2.9729E 01
 30  -5.6205E-01    1.2313E-03   -3.8031E 01   -5.2253E 01   -3.0118E 01
 31  -5.5811E-01    1.2188E-03   -3.8110E 01   -5.1951E 01   -3.0497E 01
 32  -5.5538E-01    1.2029E-03   -3.8187E 01   -5.1636E 01   -3.0868E 01
 33  -5.5365E-01    1.1859E-03   -3.8272E 01   -5.1310E 01   -3.1229E 01
 34  -5.5270E-01    1.1682E-03   -3.8352E 01   -5.0970E 01   -3.1581E 01
 35  -5.5230E-01    1.1501E-03   -3.8419E 01   -5.0613E 01   -3.1924E 01
 36  -5.5228E-01    1.1324E-03   -3.8489E 01   -5.0245E 01   -3.2259E 01
 37  -5.5247E-01    1.1155E-03   -3.8559E 01   -4.9869E 01   -3.2585E 01
 38  -5.5276E-01    1.1001E-03   -3.8626E 01   -4.9484E 01   -3.2904E 01
 39  -5.5312E-01    1.0852E-03   -3.8688E 01   -4.9091E 01   -3.3213E 01
 40  -5.5347E-01    1.0700E-03   -3.8742E 01   -4.8689E 01   -3.3513E 01
 41  -5.5374E-01    1.0558E-03   -3.8798E 01   -4.8282E 01   -3.3806E 01
```

Sample Problem Output (Cont)

```
42  -5.5394E-01    1.0427E-03  -3.8848E 01  -4.7871E 01  -3.4099E 01
43  -5.5410E-01    1.0293E-03  -3.8904E 01  -4.7456E 01  -3.4365E 01
44  -5.5421E-01    1.0159E-03  -3.8958E 01  -4.7036E 01  -3.4633E 01
45  -5.5428E-01    1.0033E-03  -3.9007E 01  -4.6611E 01  -3.4893E 01
46  -5.5433E-01    9.9074E-04  -3.9062E 01  -4.6184E 01  -3.5145E 01
47  -5.5438E-01    9.7799E-04  -3.9106E 01  -4.5749E 01  -3.5388E 01
48  -5.5440E-01    9.6517E-04  -3.9142E 01  -4.5308E 01  -3.5624E 01
49  -5.5437E-01    9.5269E-04  -3.9181E 01  -4.4863E 01  -3.5852E 01
50  -5.5432E-01    9.4037E-04  -3.9220E 01  -4.4415E 01  -3.6072E 01
51  -5.5430E-01    9.2737E-04  -3.9259E 01  -4.3962E 01  -3.6285E 01
52  -5.5428E-01    9.1511E-04  -3.9299E 01  -4.3506E 01  -3.6491E 01
53  -5.5426E-01    9.0310E-04  -3.9333E 01  -4.3043E 01  -3.6688E 01
54  -5.5426E-01    8.9061E-04  -3.9365E 01  -4.2575E 01  -3.6878E 01
55  -5.5424E-01    8.7878E-04  -3.9394E 01  -4.2102E 01  -3.7061E 01
56  -5.5422E-01    8.6703E-04  -3.9423E 01  -4.1625E 01  -3.7236E 01
57  -5.5421E-01    8.5504E-04  -3.9453E 01  -4.1145E 01  -3.7404E 01
58  -5.5424E-01    8.4304E-04  -3.9475E 01  -4.0657E 01  -3.7566E 01
59  -5.5427E-01    8.3130E-04  -3.9493E 01  -4.0164E 01  -3.7720E 01
60  -5.5428E-01    8.1978E-04  -3.9512E 01  -3.9668E 01  -3.7866E 01
61  -5.5429E-01    8.0814E-04  -3.9526E 01  -3.9166E 01  -3.8006E 01
62  -5.5428E-01    7.9664E-04  -3.9535E 01  -3.8658E 01  -3.8139E 01
63  -5.5426E-01    7.8514E-04  -3.9547E 01  -3.8147E 01  -3.8264E 01
64  -5.5425E-01    7.7365E-04  -3.9556E 01  -3.7631E 01  -3.8383E 01
65  -5.5424E-01    7.6309E-04  -3.9563E 01  -3.7113E 01  -3.8496E 01
66  -5.5425E-01    7.5284E-04  -3.9567E 01  -3.6584E 01  -3.8601E 01
67  -5.5427E-01    7.4169E-04  -3.9568E 01  -3.6053E 01  -3.8699E 01
68  -5.5428E-01    7.3084E-04  -3.9567E 01  -3.5517E 01  -3.8791E 01
69  -5.5430E-01    7.2115E-04  -3.9563E 01  -3.4976E 01  -3.8876E 01
70  -5.5432E-01    7.1085E-04  -3.9565E 01  -3.4432E 01  -3.8954E 01
71  -5.5435E-01    6.9959E-04  -3.9563E 01  -3.3881E 01  -3.9026E 01
72  -5.5440E-01    6.8895E-04  -3.9559E 01  -3.3326E 01  -3.9092E 01
73  -5.5447E-01    6.7777E-04  -3.9557E 01  -3.2769E 01  -3.9151E 01
74  -5.5460E-01    6.6492E-04  -3.9551E 01  -3.2206E 01  -3.9204E 01
75  -5.5480E-01    6.5179E-04  -3.9546E 01  -3.1640E 01  -3.9250E 01
76  -5.5504E-01    6.3825E-04  -3.9531E 01  -3.1066E 01  -3.9291E 01
77  -5.5531E-01    6.2339E-04  -3.9513E 01  -3.0486E 01  -3.9324E 01
78  -5.5558E-01    6.0675E-04  -3.9495E 01  -2.9901E 01  -3.9351E 01
79  -5.5583E-01    5.8809E-04  -3.9475E 01  -2.9309E 01  -3.9371E 01
80  -5.5599E-01    5.6807E-04  -3.9450E 01  -2.8708E 01  -3.9386E 01
81  -5.5601E-01    5.4677E-04  -3.9424E 01  -2.8099E 01  -3.9395E 01
82  -5.5580E-01    5.2531E-04  -3.9396E 01  -2.7480E 01  -3.9398E 01
83  -5.5525E-01    5.0556E-04  -3.9366E 01  -2.6852E 01  -3.9395E 01
84  -5.5427E-01    4.8851E-04  -3.9339E 01  -2.6213E 01  -3.9385E 01
```

Sample Problem Output (Cont)

```
 85  -5.5276E-01   4.7621E-04  -3.9307E 01  -2.5562E 01  -3.9370E 01
 86  -5.5058E-01   4.7274E-04  -3.9270E 01  -2.4899E 01  -3.9349E 01
 87  -5.4761E-01   4.8179E-04  -3.9233E 01  -2.4228E 01  -3.9322E 01
 88  -5.4382E-01   5.0838E-04  -3.9199E 01  -2.3551E 01  -3.9290E 01
 89  -5.3927E-01   5.5852E-04  -3.9157E 01  -2.2871E 01  -3.9252E 01
 90  -5.3407E-01   6.3607E-04  -3.9109E 01  -2.2195E 01  -3.9208E 01
 91  -5.2848E-01   7.4541E-04  -3.9062E 01  -2.1536E 01  -3.9159E 01
 92  -5.2304E-01   8.9054E-04  -3.9012E 01  -2.0905E 01  -3.9104E 01
 93  -5.1854E-01   1.0712E-03  -3.8962E 01  -2.0320E 01  -3.9043E 01
 94  -5.1611E-01   1.2831E-03  -3.8912E 01  -1.9798E 01  -3.8977E 01
 95  -5.1722E-01   1.5161E-03  -3.8865E 01  -1.9362E 01  -3.8904E 01
 96  -5.2373E-01   1.7505E-03  -3.8816E 01  -1.9031E 01  -3.8824E 01
 97  -5.3781E-01   1.9572E-03  -3.8761E 01  -1.8822E 01  -3.8737E 01
 98  -5.6191E-01   2.0944E-03  -3.8710E 01  -1.8750E 01  -3.8641E 01
 99  -5.9861E-01   2.1036E-03  -3.8660E 01  -1.8818E 01  -3.8535E 01
100  -6.5033E-01   1.9119E-03  -3.8607E 01  -1.9009E 01  -3.8420E 01
101  -7.1895E-01   1.4318E-03  -3.8559E 01  -1.9286E 01  -3.8295E 01
102  -8.0532E-01   5.6109E-04  -3.8521E 01  -1.9580E 01  -3.8158E 01
103  -9.0863E-01  -8.0947E-04  -3.8493E 01  -1.9777E 01  -3.8009E 01
104  -1.0255E 00  -2.7879E-03  -3.8465E 01  -1.9708E 01  -3.7849E 01
105  -1.1490E 00  -5.4685E-03  -3.8437E 01  -1.9151E 01  -3.7678E 01
106  -1.2676E 00  -8.9115E-03  -3.8415E 01  -1.7819E 01  -3.7501E 01
107  -1.3642E 00  -1.3117E-02  -3.8395E 01  -1.5362E 01  -3.7319E 01
108  -1.4149E 00  -1.7995E-02  -3.8369E 01  -1.1368E 01  -3.7141E 01
109  -1.3886E 00  -2.3327E-02  -3.8326E 01  -5.3916E 00  -3.6973E 01
110  -1.2462E 00  -2.8721E-02  -3.8257E 01   3.0187E 00  -3.6827E 01
111  -9.4173E-01  -3.3568E-02  -3.8144E 01   1.4269E 01  -3.6717E 01
112  -4.2329E-01  -3.6996E-02  -3.7971E 01   2.8643E 01  -3.6659E 01
113   3.6325E-01  -3.7832E-02  -3.7723E 01   4.6205E 01  -3.6670E 01
114   1.4695E 00  -3.4579E-02  -3.7380E 01   6.6676E 01  -3.6771E 01
115   2.9371E 00  -2.5420E-02  -3.6917E 01   8.9281E 01  -3.6979E 01
116   4.7876E 00  -8.2547E-03  -3.6314E 01   1.1257E 02  -3.7311E 01
117   7.0092E 00   1.9201E-02  -3.5554E 01   1.3424E 02  -3.7773E 01
118   9.5403E 00   5.9258E-02  -3.4631E 01   1.5093E 02  -3.8361E 01
119   1.2251E 01   1.1400E-01  -3.3564E 01   1.5805E 02  -3.9056E 01
120   1.4920E 01   1.7740E-01  -3.2389E 01   1.4968E 02  -3.9812E 01
121   1.7216E 01   2.4434E-01  -3.1162E 01   1.1854E 02  -4.0552E 01
```

Sample Problem Output (Cont)

```
I    SIG(PHI)     SIG(THETA)   SG(PHI,THETA)   SG2(PHI)     SG2(THETA)   SG2(PHI,THETA)

 1  -1.8441E 04  -1.1049E 04  -1.6896E 02   1.7755E 04   1.3010E 04  -1.6636E 02
 2  -1.5475E 04  -9.6127E 03  -1.6452E 02   1.4764E 04   1.2644E 04  -1.7317E 02
 3  -1.3106E 04  -8.8200E 03  -1.6369E 02   1.2381E 04   1.1974E 04  -1.7752E 02
 4  -1.1345E 04  -8.4774E 03  -1.6574E 02   1.0613E 04   1.1202E 04  -1.8072E 02
 5  -1.0125E 04  -8.4232E 03  -1.6990E 02   9.3919E 03   1.0455E 04  -1.8363E 02
 6  -9.3479E 03  -8.5327E 03  -1.7548E 02   8.6157E 03   9.8028E 03  -1.8674E 02
 7  -8.9052E 03  -8.7162E 03  -1.8190E 02   8.1752E 03   9.2728E 03  -1.9928E 02
 8  -8.6977E 03  -8.9144E 03  -1.8875E 02   7.9700E 03   8.8670E 03  -1.9435E 02
 9  -8.6421E 03  -9.0919E 03  -1.9571E 02   7.9159E 03   8.5722E 03  -1.9890E 02
10  -8.6733E 03  -9.2309E 03  -2.0260E 02   7.9481E 03   8.3684E 03  -2.0385E 02
11  -8.7446E 03  -9.3256E 03  -2.0928E 02   8.0198E 03   8.2336E 03  -2.0910E 02
12  -8.8249E 03  -9.3778E 03  -2.1571E 02   8.0995E 03   8.1476E 03  -2.1452E 02
13  -8.8954E 03  -9.3933E 03  -2.2187E 02   8.1686E 03   8.0934E 03  -2.2003E 02
14  -8.9462E 03  -9.3794E 03  -2.2777E 02   8.2177E 03   8.0576E 03  -2.2556E 02
15  -8.9741E 03  -9.3436E 03  -2.3343E 02   8.2436E 03   8.0306E 03  -2.3105E 02
16  -8.9797E 03  -9.2928E 03  -2.3889E 02   8.2469E 03   8.0059E 03  -2.3646E 02
17  -8.9658E 03  -9.2325E 03  -2.4417E 02   8.2307E 03   7.9793E 03  -2.4177E 02
18  -8.9362E 03  -9.1668E 03  -2.4928E 02   8.1988E 03   7.9490E 03  -2.4695E 02
19  -8.8948E 03  -9.0989E 03  -2.5426E 02   8.1551E 03   7.9140E 03  -2.5201E 02
20  -8.8452E 03  -9.0306E 03  -2.5911E 02   8.1032E 03   7.8744E 03  -2.5693E 02
21  -8.7902E 03  -8.9632E 03  -2.6385E 02   8.0461E 03   7.8308E 03  -2.6173E 02
22  -8.7321E 03  -8.8972E 03  -2.6848E 02   7.9860E 03   7.7840E 03  -2.6642E 02
23  -8.6727E 03  -8.8329E 03  -2.7303E 02   7.9246E 03   7.7347E 03  -2.7100E 02
24  -8.6131E 03  -8.7701E 03  -2.7748E 02   7.8630E 03   7.6837E 03  -2.7546E 02
25  -8.5537E 03  -8.7086E 03  -2.8183E 02   7.8018E 03   7.6316E 03  -2.7982E 02
26  -8.4952E 03  -8.6482E 03  -2.8609E 02   7.7413E 03   7.5788E 03  -2.8407E 02
27  -8.4375E 03  -8.5885E 03  -2.9026E 02   7.6817E 03   7.5257E 03  -2.8823E 02
28  -8.3806E 03  -8.5294E 03  -2.9434E 02   7.6232E 03   7.4726E 03  -2.9229E 02
29  -8.3243E 03  -8.4706E 03  -2.9833E 02   7.5653E 03   7.4196E 03  -2.9626E 02
30  -8.2687E 03  -8.4119E 03  -3.0222E 02   7.5081E 03   7.3668E 03  -3.0013E 02
31  -8.2135E 03  -8.3533E 03  -3.0603E 02   7.4513E 03   7.3143E 03  -3.0392E 02
32  -8.1586E 03  -8.2947E 03  -3.0974E 02   7.3949E 03   7.2619E 03  -3.0761E 02
33  -8.1041E 03  -8.2360E 03  -3.1336E 02   7.3386E 03   7.2098E 03  -3.1122E 02
34  -8.0496E 03  -8.1772E 03  -3.1689E 02   7.2825E 03   7.1578E 03  -3.1473E 02
35  -7.9950E 03  -8.1182E 03  -3.2033E 02   7.2266E 03   7.1060E 03  -3.1815E 02
36  -7.9405E 03  -8.0592E 03  -3.2368E 02   7.1707E 03   7.0543E 03  -3.2149E 02
37  -7.8860E 03  -8.0001E 03  -3.2696E 02   7.1148E 03   7.0027E 03  -3.2475E 02
38  -7.8314E 03  -7.9408E 03  -3.3014E 02   7.0589E 03   6.9512E 03  -3.2793E 02
39  -7.7767E 03  -7.8815E 03  -3.3324E 02   7.0029E 03   6.8997E 03  -3.3101E 02
40  -7.7219E 03  -7.8221E 03  -3.3625E 02   6.9471E 03   6.8483E 03  -3.3401E 02
41  -7.6671E 03  -7.7627E 03  -3.3918E 02   6.8912E 03   6.7970E 03  -3.3693E 02
```

Sample Problem Output (Cont)

```
42  -7.6122E 03  -7.7031E 03  -3.4203E 02   6.8353E 03   6.7457E 03  -3.3977E 02
43  -7.5574E 03  -7.6436E 03  -3.4479E 02   6.7793E 03   6.6944E 03  -3.4252E 02
44  -7.5025E 03  -7.5839E 03  -3.4747E 02   6.7234E 03   6.6432E 03  -3.4519E 02
45  -7.4476E 03  -7.5243E 03  -3.5007E 02   6.6674E 03   6.5920E 03  -3.4778E 02
46  -7.3927E 03  -7.4646E 03  -3.5259E 02   6.6115E 03   6.5409E 03  -3.5030E 02
47  -7.3377E 03  -7.4048E 03  -3.5504E 02   6.5556E 03   6.4898E 03  -3.5273E 02
48  -7.2826E 03  -7.3450E 03  -3.5740E 02   6.4998E 03   6.4388E 03  -3.5508E 02
49  -7.2276E 03  -7.2851E 03  -3.5968E 02   6.4440E 03   6.3878E 03  -3.5736E 02
50  -7.1726E 03  -7.2252E 03  -3.6189E 02   6.3881E 03   6.3369E 03  -3.5956E 02
51  -7.1175E 03  -7.1652E 03  -3.6402E 02   6.3323E 03   6.2860E 03  -3.6168E 02
52  -7.0625E 03  -7.1052E 03  -3.6608E 02   6.2765E 03   6.2351E 03  -3.6374E 02
53  -7.0074E 03  -7.0452E 03  -3.6806E 02   6.2207E 03   6.1843E 03  -3.6571E 02
54  -6.9523E 03  -6.9851E 03  -3.6996E 02   6.1650E 03   6.1336E 03  -3.6760E 02
55  -6.8972E 03  -6.9249E 03  -3.7179E 02   6.1093E 03   6.0829E 03  -3.6942E 02
56  -6.8420E 03  -6.8648E 03  -3.7355E 02   6.0536E 03   6.0322E 03  -3.7117E 02
57  -6.7869E 03  -6.8045E 03  -3.7523E 02   5.9979E 03   5.9816E 03  -3.7285E 02
58  -6.7317E 03  -6.7442E 03  -3.7685E 02   5.9422E 03   5.9311E 03  -3.7446E 02
59  -6.6765E 03  -6.6839E 03  -3.7839E 02   5.8866E 03   5.8806E 03  -3.7600E 02
60  -6.6212E 03  -6.6235E 03  -3.7986E 02   5.8310E 03   5.8301E 03  -3.7746E 02
61  -6.5660E 03  -6.5630E 03  -3.8125E 02   5.7754E 03   5.7797E 03  -3.7886E 02
62  -6.5106E 03  -6.5025E 03  -3.8259E 02   5.7199E 03   5.7294E 03  -3.8018E 02
63  -6.4553E 03  -6.4420E 03  -3.8385E 02   5.6644E 03   5.6791E 03  -3.8144E 02
64  -6.4000E 03  -6.3814E 03  -3.8504E 02   5.6089E 03   5.6288E 03  -3.8263E 02
65  -6.3446E 03  -6.3208E 03  -3.8617E 02   5.5534E 03   5.5786E 03  -3.8375E 02
66  -6.2893E 03  -6.2601E 03  -3.8722E 02   5.4979E 03   5.5284E 03  -3.8480E 02
67  -6.2338E 03  -6.1994E 03  -3.8821E 02   5.4425E 03   5.4783E 03  -3.8578E 02
68  -6.1784E 03  -6.1386E 03  -3.8913E 02   5.3871E 03   5.4283E 03  -3.8670E 02
69  -6.1229E 03  -6.0778E 03  -3.8998E 02   5.3317E 03   5.3782E 03  -3.8755E 02
70  -6.0675E 03  -6.0169E 03  -3.9076E 02   5.2762E 03   5.3283E 03  -3.8833E 02
71  -6.0121E 03  -5.9560E 03  -3.9148E 02   5.2208E 03   5.2783E 03  -3.8905E 02
72  -5.9566E 03  -5.8950E 03  -3.9214E 02   5.1654E 03   5.2285E 03  -3.8970E 02
73  -5.9011E 03  -5.8340E 03  -3.9273E 02   5.1100E 03   5.1786E 03  -3.9029E 02
74  -5.8456E 03  -5.7729E 03  -3.9326E 02   5.0546E 03   5.1288E 03  -3.9081E 02
75  -5.7901E 03  -5.7118E 03  -3.9373E 02   4.9992E 03   5.0790E 03  -3.9128E 02
76  -5.7345E 03  -5.6507E 03  -3.9413E 02   4.9439E 03   5.0293E 03  -3.9168E 02
77  -5.6788E 03  -5.5894E 03  -3.9446E 02   4.8885E 03   4.9797E 03  -3.9201E 02
78  -5.6231E 03  -5.5281E 03  -3.9473E 02   4.8332E 03   4.9301E 03  -3.9228E 02
79  -5.5673E 03  -5.4667E 03  -3.9494E 02   4.7778E 03   4.8805E 03  -3.9249E 02
80  -5.5115E 03  -5.4052E 03  -3.9508E 02   4.7225E 03   4.8311E 03  -3.9263E 02
81  -5.4556E 03  -5.3437E 03  -3.9517E 02   4.6671E 03   4.7817E 03  -3.9272E 02
82  -5.3997E 03  -5.2820E 03  -3.9520E 02   4.6118E 03   4.7324E 03  -3.9276E 02
83  -5.3439E 03  -5.2202E 03  -3.9516E 02   4.5565E 03   4.6832E 03  -3.9273E 02
84  -5.2881E 03  -5.1584E 03  -3.9506E 02   4.5013E 03   4.6342E 03  -3.9264E 02
```

Sample Problem Output (Cont)

```
 85  -5.2324E 03  -5.0965E 03  -3.9491E 02   4.4463E 03   4.5853E 03  -3.9250E 02
 86  -5.1769E 03  -5.0345E 03  -3.9469E 02   4.3915E 03   4.5365E 03  -3.9229E 02
 87  -5.1216E 03  -4.9725E 03  -3.9442E 02   4.3369E 03   4.4880E 03  -3.9203E 02
 88  -5.0667E 03  -4.9106E 03  -3.9410E 02   4.2827E 03   4.4396E 03  -3.9171E 02
 89  -5.0121E 03  -4.8487E 03  -3.9372E 02   4.2289E 03   4.3913E 03  -3.9133E 02
 90  -4.9579E 03  -4.7871E 03  -3.9329E 02   4.1757E 03   4.3432E 03  -3.9088E 02
 91  -4.9043E 03  -4.7258E 03  -3.9281E 02   4.1231E 03   4.2951E 03  -3.9038E 02
 92  -4.8512E 03  -4.6649E 03  -3.9228E 02   4.0710E 03   4.2468E 03  -3.8980E 02
 93  -4.7986E 03  -4.6047E 03  -3.9171E 02   4.0194E 03   4.1983E 03  -3.8916E 02
 94  -4.7465E 03  -4.5452E 03  -3.9109E 02   3.9682E 03   4.1492E 03  -3.8845E 02
 95  -4.6944E 03  -4.4866E 03  -3.9043E 02   3.9171E 03   4.0994E 03  -3.8765E 02
 96  -4.6420E 03  -4.4290E 03  -3.8970E 02   3.8656E 03   4.0484E 03  -3.8677E 02
 97  -4.5885E 03  -4.3723E 03  -3.8893E 02   3.8133E 03   3.9959E 03  -3.8580E 02
 98  -4.5332E 03  -4.3165E 03  -3.8808E 02   3.7590E 03   3.9414E 03  -3.8474E 02
 99  -4.4750E 03  -4.2611E 03  -3.8714E 02   3.7018E 03   3.8847E 03  -3.8357E 02
100  -4.4124E 03  -4.2056E 03  -3.8610E 02   3.6402E 03   3.8255E 03  -3.8231E 02
101  -4.3438E 03  -4.1492E 03  -3.8493E 02   3.5727E 03   3.7635E 03  -3.8096E 02
102  -4.2677E 03  -4.0906E 03  -3.8360E 02   3.4973E 03   3.6990E 03  -3.7955E 02
103  -4.1822E 03  -4.0281E 03  -3.8208E 02   3.4123E 03   3.6326E 03  -3.7810E 02
104  -4.0856E 03  -3.9596E 03  -3.8033E 02   3.3163E 03   3.5654E 03  -3.7665E 02
105  -3.9769E 03  -3.8824E 03  -3.7831E 02   3.2082E 03   3.4993E 03  -3.7525E 02
106  -3.8560E 03  -3.7935E 03  -3.7602E 02   3.0877E 03   3.4371E 03  -3.7399E 02
107  -3.7239E 03  -3.6899E 03  -3.7343E 02   2.9560E 03   3.3827E 03  -3.7296E 02
108  -3.5840E 03  -3.5683E 03  -3.7055E 02   2.8166E 03   3.3409E 03  -3.7226E 02
109  -3.4419E 03  -3.4261E 03  -3.6743E 02   2.6754E 03   3.3182E 03  -3.7203E 02
110  -3.3071E 03  -3.2616E 03  -3.6417E 02   2.5420E 03   3.3219E 03  -3.7238E 02
111  -3.1932E 03  -3.0748E 03  -3.6091E 02   2.4303E 03   3.3602E 03  -3.7343E 02
112  -3.1185E 03  -2.8687E 03  -3.5788E 02   2.3591E 03   3.4416E 03  -3.7529E 02
113  -3.1069E 03  -2.6499E 03  -3.5541E 02   2.3525E 03   3.5740E 03  -3.7799E 02
114  -3.1876E 03  -2.4303E 03  -3.5392E 02   2.4400E 03   3.7638E 03  -3.8150E 02
115  -3.3945E 03  -2.2282E 03  -3.5393E 02   2.6562E 03   4.0138E 03  -3.8566E 02
116  -3.7650E 03  -2.0696E 03  -3.5607E 02   3.0387E 03   4.3211E 03  -3.9315E 02
117  -4.3371E 03  -1.9898E 03  -3.6104E 02   3.6261E 03   4.6747E 03  -3.9441E 02
118  -5.1459E 03  -2.0334E 03  -3.6960E 02   4.4533E 03   5.0520E 03  -3.9763E 02
119  -6.2175E 03  -2.2547E 03  -3.8247E 02   5.5462E 03   5.4157E 03  -3.9866E 02
120  -7.5610E 03  -2.7163E 03  -4.0026E 02   6.9133E 03   5.7100E 03  -3.9598E 02
121  -9.1589E 03  -3.4864E 03  -4.2332E 02   8.5357E 03   5.8572E 03  -3.8772E 02
```

Sample Problem Output (Cont)

```
REGION  3, DEFLECTIONS AND INTERNAL LOADS, THETA =  0.0000E-39   ENF =  1.0000E 00

  I      U(I)          V(I)          W(I)         M(PHI)       M(THETA)    M(PHI,THETA)

  1  -7.8309E-02   0.0000E-39   7.5251E-03   3.0793E 01   2.0235E 01    0.0000E-39
  2  -7.8100E-02   0.0000E-39   7.9354E-03   2.5528E 01   1.8646E 01   -0.0000E-39
  3  -7.7891E-02   0.0000E-39   8.0484E-03   2.1359E 01   1.7364E 01   -0.0000E-39
  4  -7.7682E-02   0.0000E-39   7.9883E-03   1.8284E 01   1.6395E 01   -0.0000E-39
  5  -7.7469E-02   0.0000E-39   7.8457E-03   1.6174E 01   1.5704E 01   -0.0000E-39
  6  -7.7254E-02   0.0000E-39   7.6817E-03   1.4845E 01   1.5240E 01   -0.0000E-39
  7  -7.7036E-02   0.0000E-39   7.5340E-03   1.4103E 01   1.4949E 01   -0.0000E-39
  8  -7.6816E-02   0.0000E-39   7.4223E-03   1.3769E 01   1.4778E 01   -0.0000E-39
  9  -7.6593E-02   0.0000E-39   7.3537E-03   1.3695E 01   1.4685E 01   -0.0000E-39
 10  -7.6369E-02   0.0000E-39   7.3276E-03   1.3769E 01   1.4637E 01   -0.0000E-39
 11  -7.6143E-02   0.0000E-39   7.3390E-03   1.3909E 01   1.4609E 01    0.0000E-39
 12  -7.5916E-02   0.0000E-39   7.3807E-03   1.4060E 01   1.4586E 01    0.0000E-39
 13  -7.5688E-02   0.0000E-39   7.4454E-03   1.4190E 01   1.4558E 01    0.0000E-39
 14  -7.5460E-02   0.0000E-39   7.5263E-03   1.4284E 01   1.4520E 01    0.0000E-39
 15  -7.5230E-02   0.0000E-39   7.6177E-03   1.4336E 01   1.4470E 01    0.0000E-39
 16  -7.5000E-02   0.0000E-39   7.7152E-03   1.4348E 01   1.4408E 01    0.0000E-39
 17  -7.4770E-02   0.0000E-39   7.8156E-03   1.4325E 01   1.4336E 01    0.0000E-39
 18  -7.4538E-02   0.0000E-39   7.9168E-03   1.4275E 01   1.4257E 01    0.0000E-39
 19  -7.4307E-02   0.0000E-39   8.0176E-03   1.4205E 01   1.4171E 01    0.0000E-39
 20  -7.4074E-02   0.0000E-39   8.1173E-03   1.4120E 01   1.4081E 01    0.0000E-39
 21  -7.3841E-02   0.0000E-39   8.2156E-03   1.4026E 01   1.3989E 01    0.0000E-39
 22  -7.3607E-02   0.0000E-39   8.3127E-03   1.3927E 01   1.3894E 01    0.0000E-39
 23  -7.3373E-02   0.0000E-39   8.4086E-03   1.3826E 01   1.3800E 01    0.0000E-39
 24  -7.3138E-02   0.0000E-39   8.5037E-03   1.3724E 01   1.3705E 01    0.0000E-39
 25  -7.2902E-02   0.0000E-39   8.5983E-03   1.3623E 01   1.3610E 01    0.0000E-39
 26  -7.2665E-02   0.0000E-39   8.6926E-03   1.3524E 01   1.3515E 01    0.0000E-39
 27  -7.2428E-02   0.0000E-39   8.7868E-03   1.3426E 01   1.3421E 01    0.0000E-39
 28  -7.2190E-02   0.0000E-39   8.8811E-03   1.3330E 01   1.3328E 01    0.0000E-39
 29  -7.1952E-02   0.0000E-39   8.9756E-03   1.3235E 01   1.3235E 01    0.0000E-39
 30  -7.1712E-02   0.0000E-39   9.0704E-03   1.3141E 01   1.3142E 01    0.0000E-39
 31  -7.1472E-02   0.0000E-39   9.1656E-03   1.3048E 01   1.3049E 01    0.0000E-39
 32  -7.1232E-02   0.0000E-39   9.2611E-03   1.2955E 01   1.2957E 01    0.0000E-39
 33  -7.0990E-02   0.0000E-39   9.3570E-03   1.2863E 01   1.2864E 01    0.0000E-39
 34  -7.0748E-02   0.0000E-39   9.4532E-03   1.2771E 01   1.2772E 01    0.0000E-39
 35  -7.0505E-02   0.0000E-39   9.5499E-03   1.2679E 01   1.2680E 01    0.0000E-39
 36  -7.0262E-02   0.0000E-39   9.6468E-03   1.2587E 01   1.2588E 01    0.0000E-39
 37  -7.0017E-02   0.0000E-39   9.7441E-03   1.2495E 01   1.2496E 01    0.0000E-39
 38  -6.9772E-02   0.0000E-39   9.8417E-03   1.2403E 01   1.2403E 01    0.0000E-39
```

Sample Problem Output (Cont)

```
39  -6.9527E-02  0.0000E-39  9.9396E-03  1.2311E 01  1.2311E 01  0.0000E-39
40  -6.9280E-02  0.0000E-39  1.0038E-02  1.2219E 01  1.2219E 01  0.0000E-39
41  -6.9033E-02  0.0000E-39  1.0136E-02  1.2127E 01  1.2127E 01  0.0000E-39
42  -6.8785E-02  0.0000E-39  1.0235E-02  1.2035E 01  1.2034E 01  0.0000E-39
43  -6.8537E-02  0.0000E-39  1.0334E-02  1.1943E 01  1.1942E 01  0.0000E-39
44  -6.8288E-02  0.0000E-39  1.0433E-02  1.1851E 01  1.1850E 01  0.0000E-39
45  -6.8038E-02  0.0000E-39  1.0533E-02  1.1759E 01  1.1757E 01  0.0000E-39
46  -6.7787E-02  0.0000E-39  1.0632E-02  1.1666E 01  1.1665E 01  0.0000E-39
47  -6.7536E-02  0.0000E-39  1.0732E-02  1.1574E 01  1.1573E 01  0.0000E-39
48  -6.7284E-02  0.0000E-39  1.0832E-02  1.1482E 01  1.1480E 01  0.0000E-39
49  -6.7031E-02  0.0000E-39  1.0933E-02  1.1390E 01  1.1388E 01  0.0000E-39
50  -6.6777E-02  0.0000E-39  1.1033E-02  1.1297E 01  1.1296E 01  0.0000E-39
51  -6.6523E-02  0.0000E-39  1.1134E-02  1.1205E 01  1.1203E 01  0.0000E-39
52  -6.6268E-02  0.0000E-39  1.1235E-02  1.1113E 01  1.1111E 01  0.0000E-39
53  -6.6013E-02  0.0000E-39  1.1337E-02  1.1021E 01  1.1019E 01  0.0000E-39
54  -6.5756E-02  0.0000E-39  1.1438E-02  1.0928E 01  1.0926E 01  0.0000E-39
55  -6.5499E-02  0.0000E-39  1.1540E-02  1.0836E 01  1.0834E 01  0.0000E-39
56  -6.5241E-02  0.0000E-39  1.1642E-02  1.0744E 01  1.0742E 01  0.0000E-39
57  -6.4983E-02  0.0000E-39  1.1744E-02  1.0652E 01  1.0650E 01  0.0000E-39
58  -6.4724E-02  0.0000E-39  1.1847E-02  1.0560E 01  1.0557E 01  0.0000E-39
59  -6.4464E-02  0.0000E-39  1.1949E-02  1.0467E 01  1.0465E 01  0.0000E-39
60  -6.4203E-02  0.0000E-39  1.2052E-02  1.0375E 01  1.0373E 01  0.0000E-39
61  -6.3942E-02  0.0000E-39  1.2155E-02  1.0283E 01  1.0280E 01  0.0000E-39
62  -6.3680E-02  0.0000E-39  1.2258E-02  1.0191E 01  1.0188E 01  0.0000E-39
63  -6.3417E-02  0.0000E-39  1.2361E-02  1.0098E 01  1.0096E 01  0.0000E-39
64  -6.3153E-02  0.0000E-39  1.2465E-02  1.0006E 01  1.0003E 01  0.0000E-39
65  -6.2889E-02  0.0000E-39  1.256[illegible]E-02  9.9139E 00  9.9111E 00  0.0000E-39
66  -6.2624E-02  0.0000E-39  1.26[illegible]E-02  9.8217E 00  9.8187E 00  0.0000E-39
67  -6.2359E-02  0.0000E-39  1.27[illegible]E-02  9.7294E 00  9.7264E 00  0.0000E-39
68  -6.2092E-02  0.0000E-39  1.28[illegible]E-02  9.6372E 00  9.6341E 00  0.0000E-39
69  -6.1825E-02  0.0000E-39  1.29[illegible]E-02  9.5449E 00  9.5418E 00  0.0000E-39
70  -6.1558E-02  0.0000E-39  1.3089E-02  9.4527E 00  9.4495E 00  0.0000E-39
71  -6.1289E-02  0.0000E-39  1.3194E-02  9.3604E 00  9.3572E 00  0.0000E-39
72  -6.1020E-02  0.0000E-39  1.3298E-02  9.2681E 00  9.2649E 00  0.0000E-39
73  -6.0750E-02  0.0000E-39  1.3403E-02  9.1759E 00  9.1725E 00  0.0000E-39
74  -6.0480E-02  0.0000E-39  1.3508E-02  9.0836E 00  9.0802E 00  0.0000E-39
75  -6.0208E-02  0.0000E-39  1.3613E-02  8.9913E 00  8.9879E 00  0.0000E-39
76  -5.9936E-02  0.0000E-39  1.3719E-02  8.8990E 00  8.8956E 00  0.0000E-39
77  -5.9663E-02  0.0000E-39  1.3824E-02  8.8066E 00  8.8032E 00  0.0000E-39
78  -5.9390E-02  0.0000E-39  1.3930E-02  8.7142E 00  8.7109E 00  0.0000E-39
79  -5.9116E-02  0.0000E-39  1.4035E-02  8.6218E 00  8.6135E 00  0.0000E-39
80  -5.8841E-02  0.0000E-39  1.4141E-02  8.5294E 00  8.5261E 00  0.0000E-39
81  -5.8566E-02  0.0000E-39  1.4247E-02  8.4369E 00  8.4338E 00  0.0000E-39
```

Sample Problem Output (Cont)

```
 82  -5.8289E-02   0.0000E-39   1.4353E-02   8.3445E 00   8.3414E 00   0.0000E-39
 83  -5.8012E-02   0.0000E-39   1.4460E-02   8.2521E 00   8.2490E 00   0.0000E-39
 84  -5.7735E-02   0.0000E-39   1.4566E-02   8.1598E 00   8.1567E 00   0.0000E-39
 85  -5.7456E-02   0.0000E-39   1.4673E-02   8.0677E 00   8.0644E 00   0.0000E-39
 86  -5.7177E-02   0.0000E-39   1.4780E-02   7.9758E 00   7.9722E 00   0.0000E-39
 87  -5.6898E-02   0.0000E-39   1.4886E-02   7.8842E 00   7.8801E 00   0.0000E-39
 88  -5.6617E-02   0.0000E-39   1.4993E-02   7.7930E 00   7.7882E 00   0.0000E-39
 89  -5.6336E-02   0.0000E-39   1.5100E-02   7.7024E 00   7.6963E 00   0.0000E-39
 90  -5.6054E-02   0.0000E-39   1.5207E-02   7.6123E 00   7.6047E 00   0.0000E-39
 91  -5.5772E-02   0.0000E-39   1.5314E-02   7.5228E 00   7.5132E 00   0.0000E-39
 92  -5.5488E-02   0.0000E-39   1.5421E-02   7.4339E 00   7.4220E 00   0.0000E-39
 93  -5.5204E-02   0.0000E-39   1.5528E-02   7.3456E 00   7.3309E 00   0.0000E-39
 94  -5.4920E-02   0.0000E-39   1.5634E-02   7.2577E 00    .2399E 00   0.0000E-39
 95  -5.4634E-02   0.0000E-39   1.5740E-02   7.1697E 00   7.1490E 00   0.0000E-39
 96  -5.4348E-02   0.0000E-39   1.5845E-02   7.0810E 00   7.0578E 00   0.0000E-39
 97  -5.4062E-02   0.0000E-39   1.5949E-02   6.9910E 00   6.9663E 00   0.0000E-39
 98  -5.3774E-02   0.0000E-39   1.6053E-02   6.8985E 00   6.8740E 00   0.0000E-39
 99  -5.3486E-02   0.0000E-39   1.6156E-02   6.8021E 00   6.7806E 00   0.0000E-39
100  -5.3197E-02   0.0000E-39   1.6258E-02   6.7002E 00   6.6854E 00   0.0000E-39
101  -5.2907E-02   0.0000E-39   1.6359E-02   6.5919E 00   6.5881E 00   0.0000E-39
102  -5.2617E-02   0.0000E-39   1.6461E-02   6.4722E 00   6.4878E 00   0.0000E-39
103  -5.2326E-02   0.0000E-39   1.6564E-02   6.3422E 00   6.3841E 00   0.0000E-39
104  -5.2034E-02   0.0000E-39   1.6668E-02   6.1993E 00   6.2764E 00   0.0000E-39
105  -5.1741E-02   0.0000E-39   1.6777E-02   6.0426E 00   6.1643E 00   0.0000E-39
106  -5.1448E-02   0.0000E-39   1.6891E-02   5.8724E 00   6.0480E 00   0.0000E-39
107  -5.1155E-02   0.0000E-39   1.7012E-02   5.6908E 00   5.9280E 00   0.0000E-39
108  -5.0860E-02   0.0000E-39   1.7145E-02   5.5025E 00   5.8057E 00  -0.0000E-39
109  -5.0565E-02   0.0000E-39   1.7291E-02   5.3155E 00   5.6834E 00  -0.0000E-39
110  -5.0270E-02   0.0000E-39   1.7453E-02   5.1423E 00   5.5650E 00  -0.0000E-39
111  -4.9974E-02   0.0000E-39   1.7634E-02   5.0000E 00   5.4556E 00  -0.0000E-39
112  -4.9678E-02   0.0000E-39   1.7835E-02   4.9119E 00   5.3623E 00  -0.0000E-39
113  -4.9382E-02   0.0000E-39   1.8057E-02   4.9070E 00   5.2941E 00  -0.0000E-39
114  -4.9086E-02   0.0000E-39   1.8295E-02   5.0202E 00   5.2616E 00  -0.0000E-39
115  -4.8790E-02   0.0000E-39   1.8545E-02   5.2915E 00   5.2772E 00  -0.0000E-39
116  -4.8494E-02   0.0000E-39   1.8796E-02   5.7635E 00   5.3543E 00  -0.0000E-39
117  -4.8198E-02   0.0000E-39   1.9029E-02   6.4778E 00   5.5060E 00  -0.0000E-39
118  -4.7901E-02   0.0000E-39   1.9221E-02   7.4703E 00   5.7439E 00  -0.0000E-39
119  -4.7605E-02   0.0000E-39   1.9338E-02   8.7633E 00   6.0755E 00  -0.0000E-39
120  -4.7307E-02   0.0000E-39   1.9339E-02   1.0356E 01   6.5016E 00   0.0000E-39
121  -4.7007E-02   0.0000E-39   1.9174E-02   1.2212E 01   7.0120E 00   0.0000E-39
```

Sample Problem Output (Cont)

```
 I     Q(PHI)       Q(THETA)       N(PHI)       N(THETA)     N(PHI THETA)

 1  -3.3889E 01  -0.0000E-39  -3.7819E 01   8.8429E 01  -0.0000E-39
 2  -2.8101E 01  -0.0000E-39  -3.8791E 01   1.4069E 02  -0.0000E-39
 3  -2.1620E 01  -0.0000E-39  -3.9163E 01   1.4390E 02  -0.0000E-39
 4  -1.5534E 01   0.0000E-39  -3.9129E 01   1.1897E 02  -0.0000E-39
 5  -1.0305E 01   0.0000E-39  -3.8843E 01   8.0981E 01  -0.0000E-39
 6  -6.2266E 00   0.0000E-39  -3.8403E 01   3.9974E 01  -0.0000E-39
 7  -3.2541E 00   0.0000E-39  -3.7904E 01   1.9878E 00  -0.0000E-39
 8  -1.2503E 00   0.0000E-39  -3.7400E 01  -2.9902E 01  -0.0000E-39
 9  -2.6229E-02   0.0000E-39  -3.6915E 01  -5.4645E 01  -0.0000E-39
10   6.1471E-01   0.0000E-39  -3.6453E 01  -7.2455E 01  -0.0000E-39
11   8.5065E-01   0.0000E-39  -3.6017E 01  -8.4243E 01  -0.0000E-39
12   8.2880E-01   0.0000E-39  -3.5617E 01  -9.1212E 01  -0.0000E-39
13   6.6210E-01   0.0000E-39  -3.5242E 01  -9.4588E 01  -0.0000E-39
14   4.3120E-01   0.0000E-39  -3.4876E 01  -9.5474E 01  -0.0000E-39
15   1.8923E-01   0.0000E-39  -3.4517E 01  -9.4781E 01  -0.0000E-39
16  -3.2180E-02   0.0000E-39  -3.4156E 01  -9.3204E 01  -0.0000E-39
17  -2.1726E-01   0.0000E-39  -3.3790E 01  -9.1243E 01  -0.0000E-39
18  -3.6103E-01   0.0000E-39  -3.3413E 01  -8.9223E 01  -0.0000E-39
19  -4.6519E-01   0.0000E-39  -3.3024E 01  -8.7338E 01  -0.0000E-39
20  -5.3512E-01   0.0000E-39  -3.2632E 01  -8.5688E 01  -0.0000E-39
21  -5.7768E-01   0.0000E-39  -3.2220E 01  -8.4298E 01  -0.0000E-39
22  -5.9976E-01   0.0000E-39  -3.1789E 01  -8.3155E 01  -0.0000E-39
23  -6.0757E-01   0.0000E-39  -3.1356E 01  -8.2229E 01  -0.0000E-39
24  -6.0630E-01   0.0000E-39  -3.0912E 01  -8.1473E 01  -0.0000E-39
25  -5.9589E-01   0.0000E-39  -3.0456E 01  -8.0842E 01  -0.0000E-39
26  -5.9117E-01   0.0000E-39  -2.9999E 01  -8.0299E 01  -0.0000E-39
27  -5.8207E-01   0.0000E-39  -2.9528E 01  -7.9806E 01  -0.0000E-39
28  -5.7367E-01   0.0000E-39  -2.9041E 01  -7.9338E 01  -0.0000E-39
29  -5.6656E-01   0.0000E-39  -2.8548E 01  -7.8878E 01  -0.0000E-39
30  -5.6097E-01   0.0000E-39  -2.8049E 01  -7.8414E 01  -0.0000E-39
31  -5.5685E-01   0.0000E-39  -2.7542E 01  -7.7938E 01  -0.0000E-39
32  -5.5402E-01   0.0000E-39  -2.7029E 01  -7.7446E 01  -0.0000E-39
33  -5.5225E-01   0.0000E-39  -2.6519E 01  -7.6940E 01  -0.0000E-39
34  -5.5129E-01   0.0000E-39  -2.6000E 01  -7.6416E 01  -0.0000E-39
35  -5.5090E-01   0.0000E-39  -2.5464E 01  -7.5872E 01  -0.0000E-39
36  -5.5089E-01   0.0000E-39  -2.4926E 01  -7.5315E 01  -0.0000E-39
37  -5.5111E-01   0.0000E-39  -2.4385E 01  -7.4747E 01  -0.0000E-39
38  -5.5143E-01   0.0000E-39  -2.3839E 01  -7.4167E 01  -0.0000E-39
39  -5.5181E-01   0.0000E-39  -2.3283E 01  -7.3577E 01  -0.0000E-39
40  -5.5219E-01   0.0000E-39  -2.2717E 01  -7.2976E 01  -0.0000E-39
41  -5.5247E-01   0.0000E-39  -2.2150E 01  -7.2368E 01  -0.0000E-39
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Sample Problem Output (Cont)

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42  -5.5269E-01   0.0000E-39  -2.1575E 01  -7.1751E 01  -0.0000E-39
43  -5.5285E-01   0.0000E-39  -2.1002E 01  -7.1129E 01  -0.0000E-39
44  -5.5297E-01   0.0000E-39  -2.0427E 01  -7.0500E 01  -0.0000E-39
45  -5.5305E-01   0.0000E-39  -1.9845E 01  -6.9864E 01  -0.0000E-39
46  -5.5310E-01   0.0000E-39  -1.9266E 01  -6.9222E 01  -0.0000E-39
47  -5.5315E-01   0.0000E-39  -1.8675E 01  -6.8571E 01  -0.0000E-39
48  -5.5318E-01   0.0000E-39  -1.8075E 01  -6.7910E 01  -0.0000E-39
49  -5.5315E-01   0.0000E-39  -1.7476E 01  -6.7244E 01  -0.0000E-39
50  -5.5310E-01   0.0000E-39  -1.6877E 01  -6.6572E 01  -0.0000E-39
51  -5.5308E-01   0.0000E-39  -1.6276E 01  -6.5893E 01  -0.0000E-39
52  -5.5305E-01   0.0000E-39  -1.5677E 01  -6.5208E 01  -0.0000E-39
53  -5.5304E-01   0.0000E-39  -1.5072E 01  -6.4514E 01  -0.0000E-39
54  -5.5304E-01   0.0000E-39  -1.4463E 01  -6.3813E 01  -0.0000E-39
55  -5.5303E-01   0.0000E-39  -1.3853E 01  -6.3104E 01  -0.0000E-39
56  -5.5302E-01   0.0000E-39  -1.3240E 01  -6.2388E 01  -0.0000E-39
57  -5.5303E-01   0.0000E-39  -1.2630E 01  -6.1666E 01  -0.0000E-39
58  -5.5306E-01   0.0000E-39  -1.2012E 01  -6.0935E 01  -0.0000E-39
59  -5.5309E-01   0.0000E-39  -1.1391E 01  -6.0196E 01  -0.0000E-39
60  -5.5310E-01   0.0000E-39  -1.0771E 01  -5.9451E 01  -0.0000E-39
61  -5.5312E-01   0.0000E-39  -1.0146E 01  -5.8698E 01  -0.0000E-39
62  -5.5312E-01   0.0000E-39  -9.5179E 00  -5.7937E 01  -0.0000E-39
63  -5.5309E-01   0.0000E-39  -8.8927E 00  -5.7170E 01  -0.0000E-39
64  -5.5309E-01   0.0000E-39  -8.2680E 00  -5.6396E 01  -0.0000E-39
65  -5.5309E-01   0.0000E-39  -7.6420E 00  -5.5615E 01  -0.0000E-39
66  -5.5311E-01   0.0000E-39  -7.0144E 00  -5.4826E 01  -0.0000E-39
67  -5.5314E-01   0.0000E-39  -6.3850E 00  -5.4030E 01  -0.0000E-39
68  -5.5315E-01   0.0000E-39  -5.7537E 00  -5.3226E 01  -0.0000E-39
69  -5.5318E-01   0.0000E-39  -5.1228E 00  -5.2414E 01  -0.0000E-39
70  -5.5321E-01   0.0000E-39  -4.4989E 00  -5.1597E 01  -0.0000E-39
71  -5.5323E-01   0.0000E-39  -3.8734E 00  -5.0770E 01  -0.0000E-39
72  -5.5327E-01   0.0000E-39  -3.2485E 00  -4.9937E 01  -0.0000E-39
73  -5.5331E-01   0.0000E-39  -2.6266E 00  -4.9099E 01  -0.0000E-39
74  -5.5340E-01   0.0000E-39  -2.0045E 00  -4.8253E 01  -0.0000E-39
75  -5.5355E-01   0.0000E-39  -1.3848E 00  -4.7400E 01  -0.0000E-39
76  -5.5373E-01   0.0000E-39  -7.5826E-01  -4.6538E 01  -0.0000E-39
77  -5.5392E-01   0.0000E-39  -1.3106E-01  -4.5668E 01  -0.0000E-39
78  -5.5412E-01   0.0000E-39   4.9362E-01  -4.4790E 01  -0.0000E-39
79  -5.5428E-01   0.0000E-39   1.1174E 00  -4.3903E 01  -0.0000E-39
80  -5.5439E-01   0.0000E-39   1.7437E 00  -4.3006E 01  -0.0000E-39
81  -5.5437E-01   0.0000E-39   2.3688E 00  -4.2099E 01  -0.0000E-39
82  -5.5417E-01   0.0000E-39   2.9926E 00  -4.1181E 01  -0.0000E-39
83  -5.5371E-01   0.0000E-39   3.6146E 00  -4.0252E 01  -0.0000E-39
84  -5.5293E-01   0.0000E-39   4.2306E 00  -3.9313E 01  -0.0000E-39
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Sample Problem Output (Cont)

```
 85  -5.5176E-01   0.0000E-39    4.8482E 00   -3.8362E 01   -0.0000E-39
 86  -5.5012E-01   0.0000E-39    5.4673E 00   -3.7398E 01   -0.0000E-39
 87  -5.4792E-01   0.0000E-39    6.0831E 00   -3.6425E 01   -0.0000E-39
 88  -5.4517E-01   0.0000E-39    6.6924E 00   -3.5446E 01   -0.0000E-39
 89  -5.4193E-01   0.0000E-39    7.3064E 00   -3.4461E 01   -0.0000E-39
 90  -5.3831E-01   0.0000E-39    7.9221E 00   -3.3477E 01   -0.0000E-39
 91  -5.3452E-01   0.0000E-39    8.5335E 00   -3.2504E 01   -0.0000E-39
 92  -5.3098E-01   0.0000E-39    9.1438E 00   -3.1548E 01   -0.0000E-39
 93  -5.2831E-01   0.0000E-39    9.7502E 00   -3.0624E 01   -0.0000E-39
 94  -5.2736E-01   0.0000E-39    1.0352E 01   -2.9745E 01   -0.0000E-39
 95  -5.2921E-01   0.0000E-39    1.0948E 01   -2.8924E 01   -0.0000E-39
 96  -5.3521E-01   0.0000E-39    1.1542E 01   -2.8174E 01   -0.0000E-39
 97  -5.4690E-01   0.0000E-39    1.2139E 01   -2.7506E 01   -0.0000E-39
 98  -5.6597E-01   0.0000E-39    1.2728E 01   -2.6929E 01   -0.0000E-39
 99  -5.9414E-01   0.0000E-39    1.3312E 01   -2.6439E 01   -0.0000E-39
100  -6.3296E-01   0.0000E-39    1.3896E 01   -2.6021E 01   -0.0000E-39
101  -6.8347E-01   0.0000E-39    1.4473E 01   -2.5642E 01   -0.0000E-39
102  -7.4589E-01   0.0000E-39    1.5037E 01   -2.5246E 01   -0.0000E-39
103  -8.1909E-01  -0.0000E-39    1.5587E 01   -2.4746E 01   -0.0000E-39
104  -9.0001E-01  -0.0000E-39    1.6136E 01   -2.4011E 01   -0.0000E-39
105  -9.8290E-01  -0.0000E-39    1.6681E 01   -2.2877E 01   -0.0000E-39
106  -1.0587E 00  -0.0000E-39    1.7218E 01   -2.1136E 01   -0.0000E-39
107  -1.1142E 00  -0.0000E-39    1.7749E 01   -1.8536E 01   -0.0000E-39
108  -1.1317E 00  -0.0000E-39    1.8281E 01   -1.4790E 01   -0.0000E-39
109  -1.0880E 00  -0.0000E-39    1.8822E 01   -9.5944E 00   -0.0000E-39
110  -9.5535E-01  -0.0000E-39    1.9381E 01   -2.6540E 00   -0.0000E-39
111  -7.0097E-01  -0.0000E-39    1.9971E 01    6.2790E 00   -0.0000E-39
112  -2.8930E-01  -0.0000E-39    2.0604E 01    1.7345E 01   -0.0000E-39
113   3.1574E-01  -0.0000E-39    2.1291E 01    3.0509E 01   -0.0000E-39
114   1.1467E 00  -0.0000E-39    2.2045E 01    4.5462E 01   -0.0000E-39
115   2.2270E 00  -0.0000E-39    2.2886E 01    6.1525E 01   -0.0000E-39
116   3.5633E 00  -0.0000E-39    2.3830E 01    7.7516E 01   -0.0000E-39
117   5.1356E 00   0.0000E-39    2.4886E 01    9.1626E 01   -0.0000E-39
118   6.8861E 00   0.0000E-39    2.6059E 01    1.0129E 02   -0.0000E-39
119   8.7049E 00   0.0000E-39    2.7332E 01    1.0310E 02   -0.0000E-39
120   1.0416E 01   0.0000E-39    2.8672E 01    9.2735E 01   -0.0000E-39
121   1.1764E 01   0.0000E-39    3.0038E 01    6.4973E 01   -0.0000E-39
```

Sample Problem Output (Cont)

```
  I    SIG(PHI)     SIG(THETA)   SG(PHI,THETA)   SG2(PHI)     SG2(THETA)   SG2(PHI,THETA)

  1  -1.8854E 04  -1.1257E 04  -0.0000E-39    1.8097E 04   1.3025E 04  -0.0000E-39
  2  -1.5705E 04  -9.7806E 03  -0.0000E-39    1.4929E 04   1.2594E 04  -0.0000E-39
  3  -1.3207E 04  -8.9794E 03  -0.0000E-39    1.2424E 04   1.1857E 04  -0.0000E-39
  4  -1.1362E 04  -8.6471E 03  -0.0000E-39    1.0579E 04   1.1027E 04  -0.0000E-39
  5  -1.0093E 04  -8.6125E 03  -0.0000E-39    9.3160E 03   1.0232E 04  -0.0000E-39
  6  -9.2911E 03  -8.7445E 03  -0.0000E-39    8.5231E 03   9.5440E 03  -0.0000E-39
  7  -8.8407E 03  -8.9494E 03  -0.0000E-39    8.0826E 03   8.9892E 03  -0.0000E-39
  8  -8.6353E 03  -9.1659E 03  -0.0000E-39    7.8873E 03   8.5678E 03  -0.0000E-39
  9  -8.5866E 03  -9.3576E 03  -0.0000E-39    7.8483E 03   8.2647E 03  -0.0000E-39
 10  -8.6262E 03  -9.5068E 03  -0.0000E-39    7.8972E 03   8.0576E 03  -0.0000E-39
 11  -8.7054E 03  -9.6080E 03  -0.0000E-39    7.9851E 03   7.9232E 03  -0.0000E-39
 12  -8.7919E 03  -9.6638E 03  -0.0000E-39    8.0795E 03   7.8396E 03  -0.0000E-39
 13  -8.8663E 03  -9.6806E 03  -0.0000E-39    8.1615E 03   7.7889E 03  -0.0000E-39
 14  -8.9189E 03  -9.6665E 03  -0.0000E-39    8.2214E 03   7.7570E 03  -0.0000E-39
 15  -8.9465E 03  -9.6295E 03  -0.0000E-39    8.2562E 03   7.7339E 03  -0.0000E-39
 16  -8.9502E 03  -9.5768E 03  -0.0000E-39    8.2671E 03   7.7127E 03  -0.0000E-39
 17  -8.9331E 03  -9.5143E 03  -0.0000E-39    8.2573E 03   7.6894E 03  -0.0000E-39
 18  -8.8993E 03  -9.4463E 03  -0.0000E-39    8.2311E 03   7.6618E 03  -0.0000E-39
 19  -8.8531E 03  -9.3760E 03  -0.0000E-39    8.1926E 03   7.6293E 03  -0.0000E-39
 20  -8.7982E 03  -9.3056E 03  -0.0000E-39    8.1456E 03   7.5918E 03  -0.0000E-39
 21  -8.7377E 03  -9.2361E 03  -0.0000E-39    8.0933E 03   7.5502E 03  -0.0000E-39
 22  -8.6740E 03  -9.1682E 03  -0.0000E-39    8.0382E 03   7.5051E 03  -0.0000E-39
 23  -8.6089E 03  -9.1020E 03  -0.0000E-39    7.9818E 03   7.4574E 03  -0.0000E-39
 24  -8.5435E 03  -9.0375E 03  -0.0000E-39    7.9253E 03   7.4080E 03  -0.0000E-39
 25  -8.4785E 03  -8.9743E 03  -0.0000E-39    7.8694E 03   7.3574E 03  -0.0000E-39
 26  -8.4143E 03  -8.9122E 03  -0.0000E-39    7.8143E 03   7.3062E 03  -0.0000E-39
 27  -8.3509E 03  -8.8509E 03  -0.0000E-39    7.7603E 03   7.2548E 03  -0.0000E-39
 28  -8.2882E 03  -8.7901E 03  -0.0000E-39    7.7074E 03   7.2033E 03  -0.0000E-39
 29  -8.2263E 03  -8.7296E 03  -0.0000E-39    7.6553E 03   7.1520E 03  -0.0000E-39
 30  -8.1649E 03  -8.6693E 03  -0.0000E-39    7.6040E 03   7.1010E 03  -0.0000E-39
 31  -8.1040E 03  -8.6089E 03  -0.0000E-39    7.5532E 03   7.0502E 03  -0.0000E-39
 32  -8.0433E 03  -8.5486E 03  -0.0000E-39    7.5028E 03   6.9996E 03  -0.0000E-39
 33  -7.9829E 03  -8.4881E 03  -0.0000E-39    7.4525E 03   6.9493E 03  -0.0000E-39
 34  -7.9226E 03  -8.4275E 03  -0.0000E-39    7.4025E 03   6.8992E 03  -0.0000E-39
 35  -7.8621E 03  -8.3667E 03  -0.0000E-39    7.3528E 03   6.8492E 03  -0.0000E-39
 36  -7.8016E 03  -8.3058E 03  -0.0000E-39    7.3031E 03   6.7995E 03  -0.0000E-39
 37  -7.7411E 03  -8.2448E 03  -0.0000E-39    7.2534E 03   6.7499E 03  -0.0000E-39
 38  -7.6804E 03  -8.1837E 03  -0.0000E-39    7.2037E 03   6.7003E 03  -0.0000E-39
 39  -7.6197E 03  -8.1224E 03  -0.0000E-39    7.1540E 03   6.6509E 03  -0.0000E-39
 40  -7.5588E 03  -8.0611E 03  -0.0000E-39    7.1045E 03   6.6015E 03  -0.0000E-39
 41  -7.4979E 03  -7.9996E 03  -0.0000E-39    7.0549E 03   6.5523E 03  -0.0000E-39
```

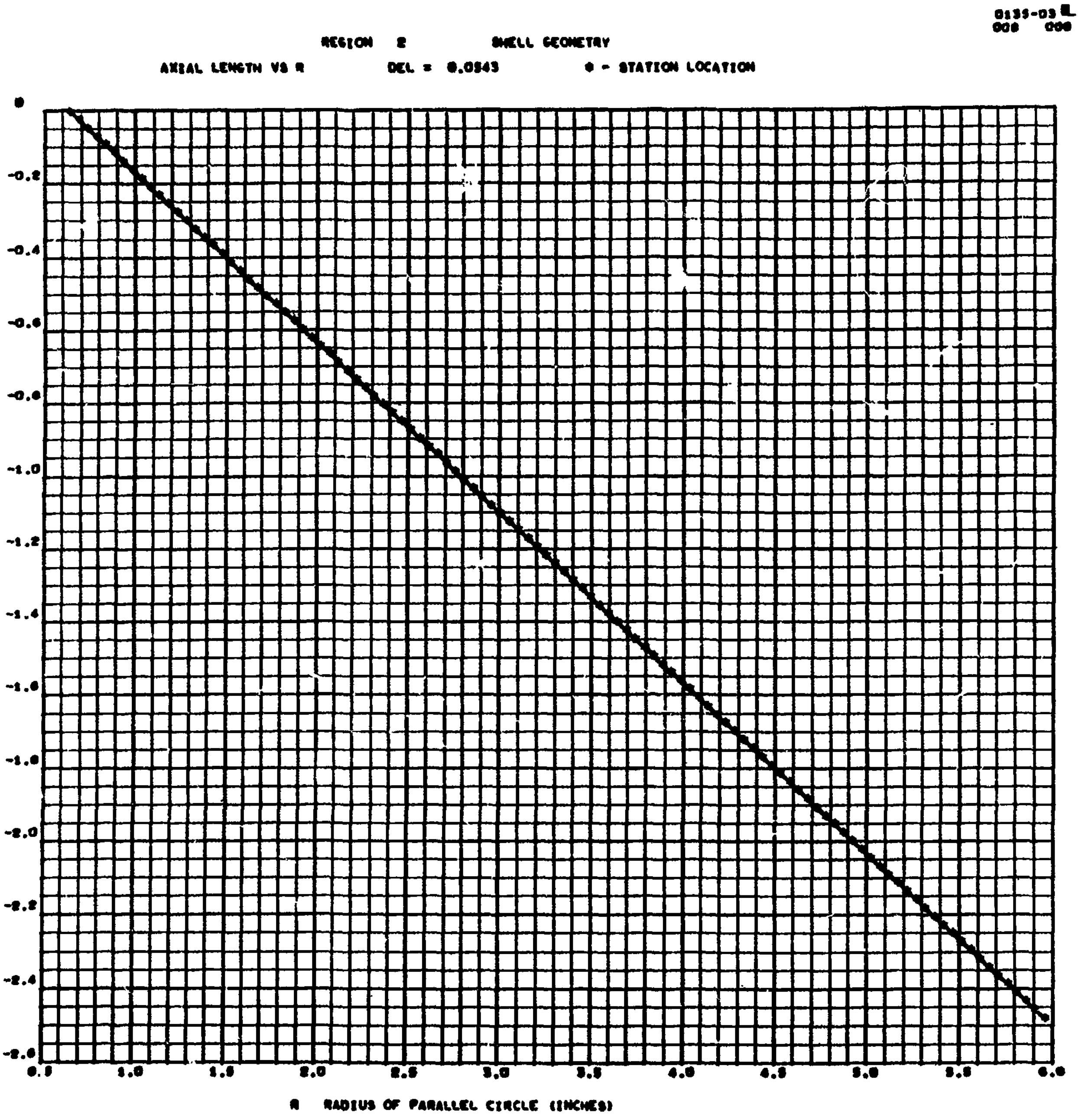
Sample Problem Output (Cont)

```
 42  -7.4368E 03  -7.9381E 03  -0.0000E-39   7.0053E 03   6.5030E 03  -0.0000E-39
 43  -7.3758E 03  -7.8765E 03  -0.0000E-39   6.9558E 03   6.4539E 03  -0.0000E-39
 44  -7.3147E 03  -7.8148E 03  -0.0000E-39   6.9062E 03   6.4048E 03  -0.0000E-39
 45  -7.2536E 03  -7.7530E 03  -0.0000E-39   6.8567E 03   6.3558E 03  -0.0000E-39
 46  -7.1925E 03  -7.6912E 03  -0.0000E-39   6.8071E 03   6.3068E 03  -0.0000E-39
 47  -7.1312E 03  -7.6293E 03  -0.0000E-39   6.7577E 03   6.2579E 03  -0.0000E-39
 48  -7.0699E 03  -7.5673E 03  -0.0000E-39   6.7083E 03   6.2091E 03  -0.0000E-39
 49  -7.0085E 03  -7.5053E 03  -0.0000E-39   6.6590E 03   6.1604E 03  -0.0000E-39
 50  -6.9472E 03  -7.4432E 03  -0.0000E-39   6.6096E 03   6.1117E 03  -0.0000E-39
 51  -6.8858E 03  -7.3810E 03  -0.0000E-39   6.5603E 03   6.0631E 03  -0.0000E-39
 52  -6.8245E 03  -7.3187E 03  -0.0000E-39   6.5110E 03   6.0146E 03  -0.0000E-39
 53  -6.7631E 03  -7.2564E 03  -0.0000E-39   6.4617E 03   5.9661E 03  -0.0000E-39
 54  -6.7017E 03  -7.1940E 03  -0.0000E-39   6.4124E 03   5.9178E 03  -0.0000E-39
 55  -6.6403E 03  -7.1315E 03  -0.0000E-39   6.3632E 03   5.8695E 03  -0.0000E-39
 56  -6.5788E 03  -7.0690E 03  -0.0000E-39   6.3140E 03   5.8212E 03  -0.0000E-39
 57  -6.5174E 03  -7.0064E 03  -0.0000E-39   6.2648E 03   5.7731E 03  -0.0000E-39
 58  -6.4558E 03  -6.9437E 03  -0.0000E-39   6.2156E 03   5.7250E 03  -0.0000E-39
 59  -6.3943E 03  -6.8809E 03  -0.0000E-39   6.1665E 03   5.6770E 03  -0.0000E-39
 60  -6.3328E 03  -6.8181E 03  -0.0000E-39   6.1173E 03   5.6291E 03  -0.0000E-39
 61  -6.2712E 03  -6.7552E 03  -0.0000E-39   6.0682E 03   5.5812E 03  -0.0000E-39
 62  -6.2095E 03  -6.6922E 03  -0.0000E-39   6.0192E 03   5.5334E 03  -0.0000E-39
 63  -6.1479E 03  -6.6291E 03  -0.0000E-39   5.9701E 03   5.4857E 03  -0.0000E-39
 64  -6.0864E 03  -6.5660E 03  -0.0000E-39   5.9210E 03   5.4381E 03  -0.0000E-39
 65  -6.0248E 03  -6.5028E 03  -0.0000E-39   5.8719E 03   5.3905E 03  -0.0000E-39
 66  -5.9631E 03  -6.4395E 03  -0.0000E-39   5.8228E 03   5.3430E 03  -0.0000E-39
 67  -5.9015E 03  -6.3762E 03  -0.0000E-39   5.7738E 03   5.2956E 03  -0.0000E-39
 68  -5.8398E 03  -6.3127E 03  -0.0000E-39   5.7248E 03   5.2482E 03  -0.0000E-39
 69  -5.7782E 03  -6.2492E 03  -0.0000E-39   5.6757E 03   5.2009E 03  -0.0000E-39
 70  -5.7166E 03  -6.1857E 03  -0.0000E-39   5.6266E 03   5.1537E 03  -0.0000E-39
 71  -5.6550E 03  -6.1220E 03  -0.0000E-39   5.5775E 03   5.1066E 03  -0.0000E-39
 72  -5.5934E 03  -6.0583E 03  -0.0000E-39   5.5284E 03   5.0595E 03  -0.0000E-39
 73  -5.5318E 03  -5.9945E 03  -0.0000E-39   5.4793E 03   5.0125E 03  -0.0000E-39
 74  -5.4702E 03  -5.9307E 03  -0.0000E-39   5.4301E 03   4.9656E 03  -0.0000E-39
 75  -5.4086E 03  -5.8667E 03  -0.0000E-39   5.3809E 03   4.9187E 03  -0.0000E-39
 76  -5.3470E 03  -5.8027E 03  -0.0000E-39   5.3318E 03   4.8720E 03  -0.0000E-39
 77  -5.2853E 03  -5.7386E 03  -0.0000E-39   5.2827E 03   4.8253E 03  -0.0000E-39
 78  -5.2236E 03  -5.6744E 03  -0.0000E-39   5.2335E 03   4.7786E 03  -0.0000E-39
 79  -5.1619E 03  -5.6101E 03  -0.0000E-39   5.1843E 03   4.7321E 03  -0.0000E-39
 80  -5.1002E 03  -5.5457E 03  -0.0000E-39   5.1351E 03   4.6856E 03  -0.0000E-39
 81  -5.0385E 03  -5.4813E 03  -0.0000E-39   5.0858E 03   4.6393E 03  -0.0000E-39
 82  -4.9768E 03  -5.4167E 03  -0.0000E-39   5.0366E 03   4.5930E 03  -0.0000E-39
 83  -4.9151E 03  -5.3520E 03  -0.0000E-39   4.9874E 03   4.5469E 03  -0.0000E-39
 84  -4.8536E 03  -5.2872E 03  -0.0000E-39   4.9382E 03   4.5009E 03  -0.0000E-39
```

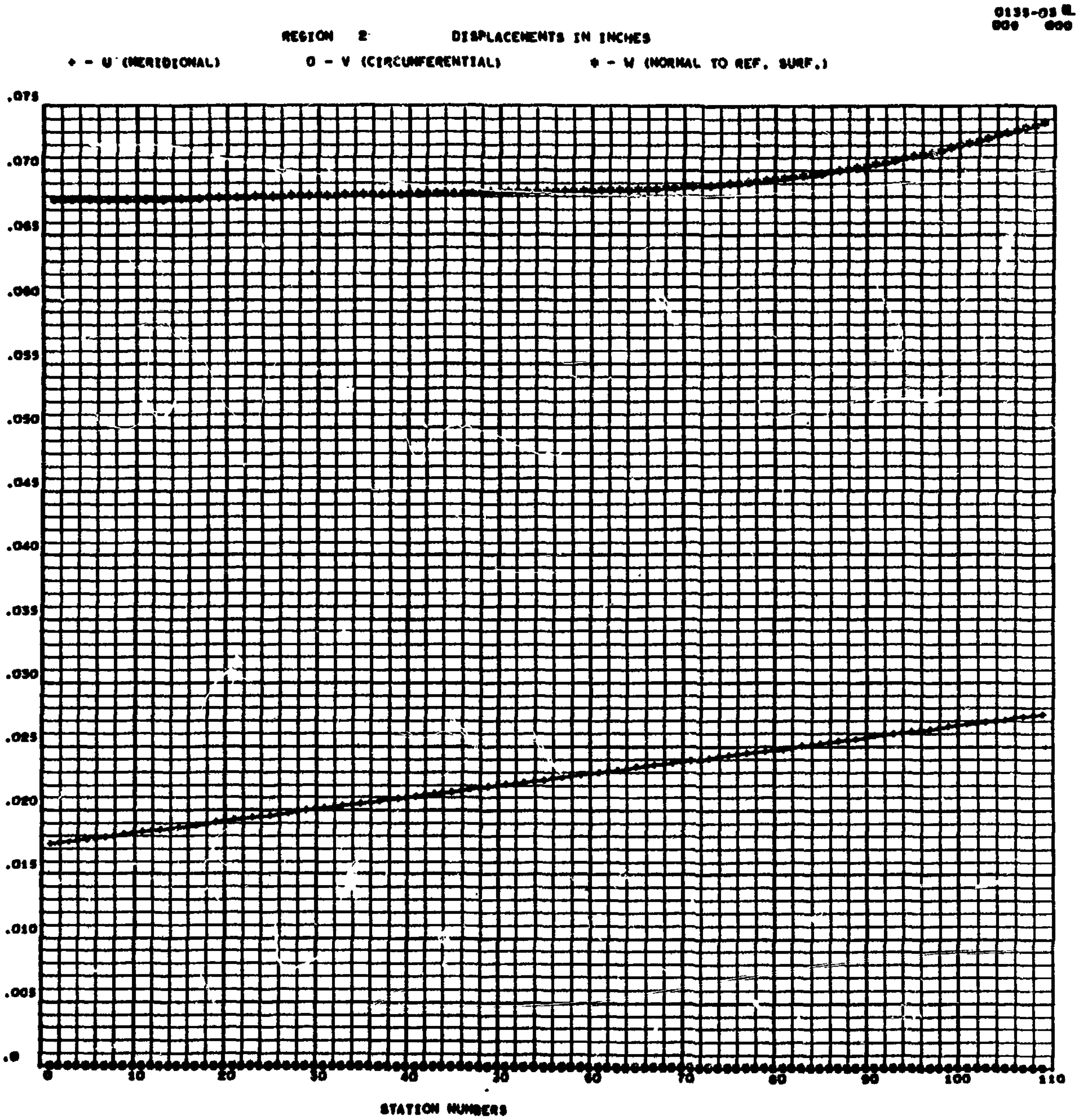
Sample Problem Output (Cont)

```
 85  -4.7921E 03  -5.2223E 03  -0.0000E-39   4.8891E 03   4.4551E 03  -0.0000E-39
 86  -4.7308E 03  -5.1573E 03  -0.0000E-39   4.8401E 03   4.4094E 03  -0.0000E-39
 87  -4.6697E 03  -5.0923E 03  -0.0000E-39   4.7913E 03   4.3638E 03  -0.0000E-39
 88  -4.6089E 03  -5.0274E 03  -0.0000E-39   4.7427E 03   4.3184E 03  -0.0000E-39
 89  -4.5484E 03  -4.9624E 03  -0.0000E-39   4.6945E 03   4.2732E 03  -0.0000E-39
 90  -4.4881E 03  -4.8976E 03  -0.0000E-39   4.6466E 03   4.2280E 03  -0.0000E-39
 91  -4.4283E 03  -4.8330E 03  -0.0000E-39   4.5990E 03   4.1829E 03  -0.0000E-39
 92  -4.3689E 03  -4.7687E 03  -0.0000E-39   4.5518E 03   4.1377E 03  -0.0000E-39
 93  -4.3099E 03  -4.7048E 03  -0.0000E-39   4.5049E 03   4.0923E 03  -0.0000E-39
 94  -4.2511E 03  -4.6414E 03  -0.0000E-39   4.4581E 03   4.0465E 03  -0.0000E-39
 95  -4.1923E 03  -4.5786E 03  -0.0000E-39   4.4113E 03   4.0001E 03  -0.0000E-39
 96  -4.1332E 03  -4.5164E 03  -0.0000E-39   4.3640E 03   3.9530E 03  -0.0000E-39
 97  -4.0732E 03  -4.4548E 03  -0.0000E-39   4.3160E 03   3.9047E 03  -0.0000E-39
 98  -4.0118E 03  -4.3937E 03  -0.0000E-39   4.2664E 03   3.8551E 03  -0.0000E-39
 99  -3.9481E 03  -4.3327E 03  -0.0000E-39   4.2144E 03   3.8039E 03  -0.0000E-39
100  -3.8811E 03  -4.2715E 03  -0.0000E-39   4.1591E 03   3.7511E 03  -0.0000E-39
101  -3.8098E 03  -4.2093E 03  -0.0000E-39   4.0993E 03   3.6964E 03  -0.0000E-39
102  -3.7330E 03  -4.1452E 03  -0.0000E-39   4.0337E 03   3.6402E 03  -0.0000E-39
103  -3.6495E 03  -4.0779E 03  -0.0000E-39   3.9612E 03   3.5830E 03  -0.0000E-39
104  -3.5582E 03  -4.0059E 03  -0.0000E-39   3.8809E 03   3.5257E 03  -0.0000E-39
105  -3.4587E 03  -3.9274E 03  -0.0000E-39   3.7924E 03   3.4698E 03  -0.0000E-39
106  -3.3512E 03  -3.8401E 03  -0.0000E-39   3.6956E 03   3.4174E 03  -0.0000E-39
107  -3.2370E 03  -3.7421E 03  -0.0000E-39   3.5920E 03   3.3714E 03  -0.0000E-39
108  -3.1187E 03  -3.6313E 03  -0.0000E-39   3.4843E 03   3.3355E 03  -0.0000E-39
109  -3.0011E 03  -3.5060E 03  -0.0000E-39   3.3775E 03   3.3141E 03  -0.0000E-39
110  -2.8916E 03  -3.3655E 03  -0.0000E-39   3.2792E 03   3.3125E 03  -0.0000E-39
111  -2.8003E 03  -3.2106E 03  -0.0000E-39   3.1997E 03   3.3362E 03  -0.0000E-39
112  -2.7411E 03  -3.0439E 03  -0.0000E-39   3.1532E 03   3.3909E 03  -0.0000E-39
113  -2.7313E 03  -2.8713E 03  -0.0000E-39   3.1571E 03   3.4815E 03  -0.0000E-39
114  -2.7917E 03  -2.7023E 03  -0.0000E-39   3.2326E 03   3.6116E 03  -0.0000E-39
115  -2.9461E 03  -2.5511E 03  -0.0000E-39   3.4038E 03   3.7816E 03  -0.0000E-39
116  -3.2198E 03  -2.4374E 03  -0.0000E-39   3.6964E 03   3.9878E 03  -0.0000E-39
117  -3.6378E 03  -2.3874E 03  -0.0000E-39   4.1355E 03   4.2199E 03  -0.0000E-39
118  -4.2216E 03  -2.4334E 03  -0.0000E-39   4.7428E 03   4.4593E 03  -0.0000E-39
119  -4.9846E 03  -2.6143E 03  -0.0000E-39   5.5313E 03   4.6764E 03  -0.0000E-39
120  -5.9268E 03  -2.9736E 03  -0.0000E-39   6.5902E 03   4.8283E 03  -0.0000E-39
121  -7.0266E 03  -3.5575E 03  -0.0000E-39   7.6273E 03   4.8569E 03  -0.0000E-39
```

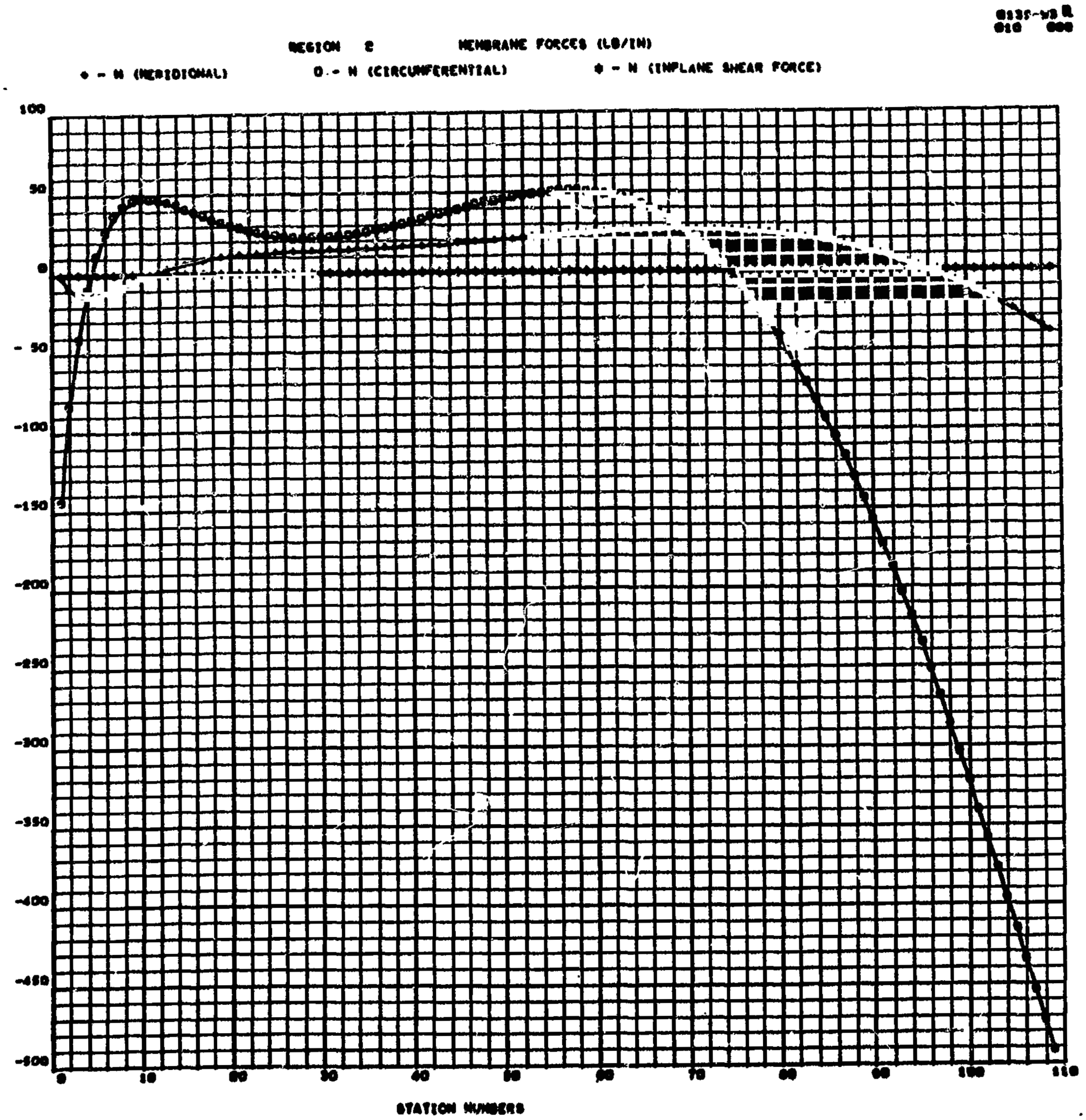
Sample Problem Output (Cont)



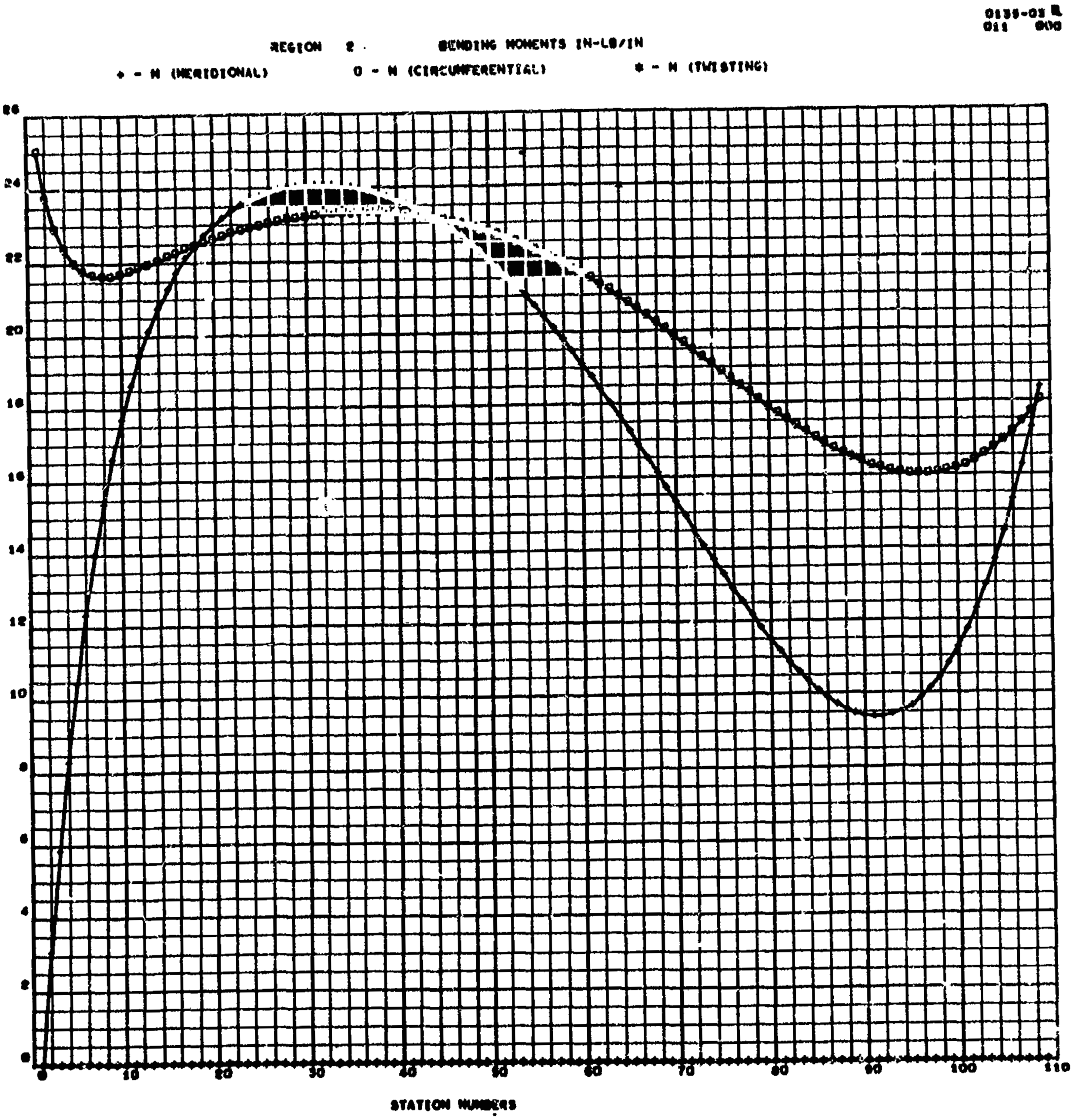
Sample CRT Results



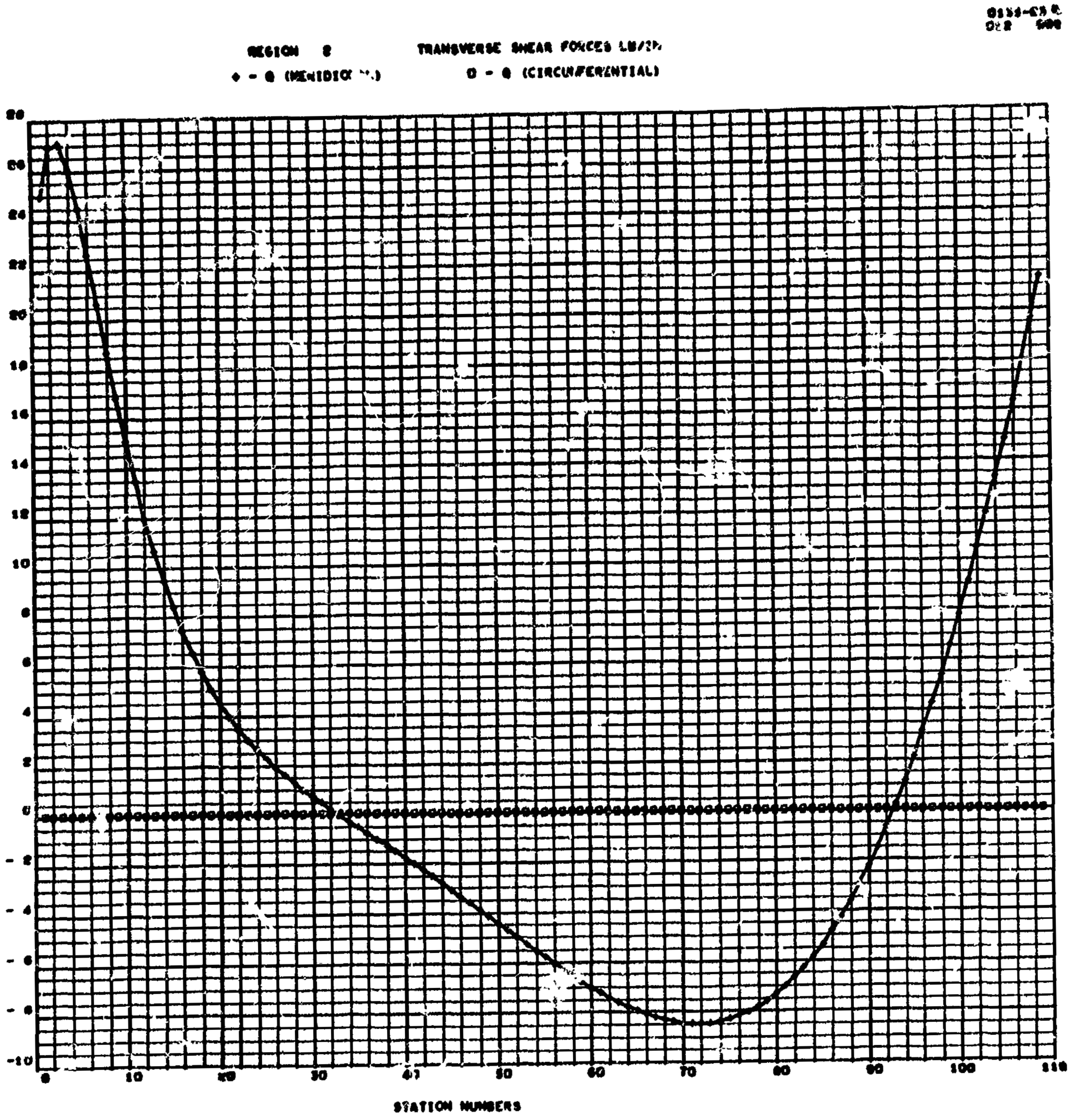
Sample CRT Results (Cont)



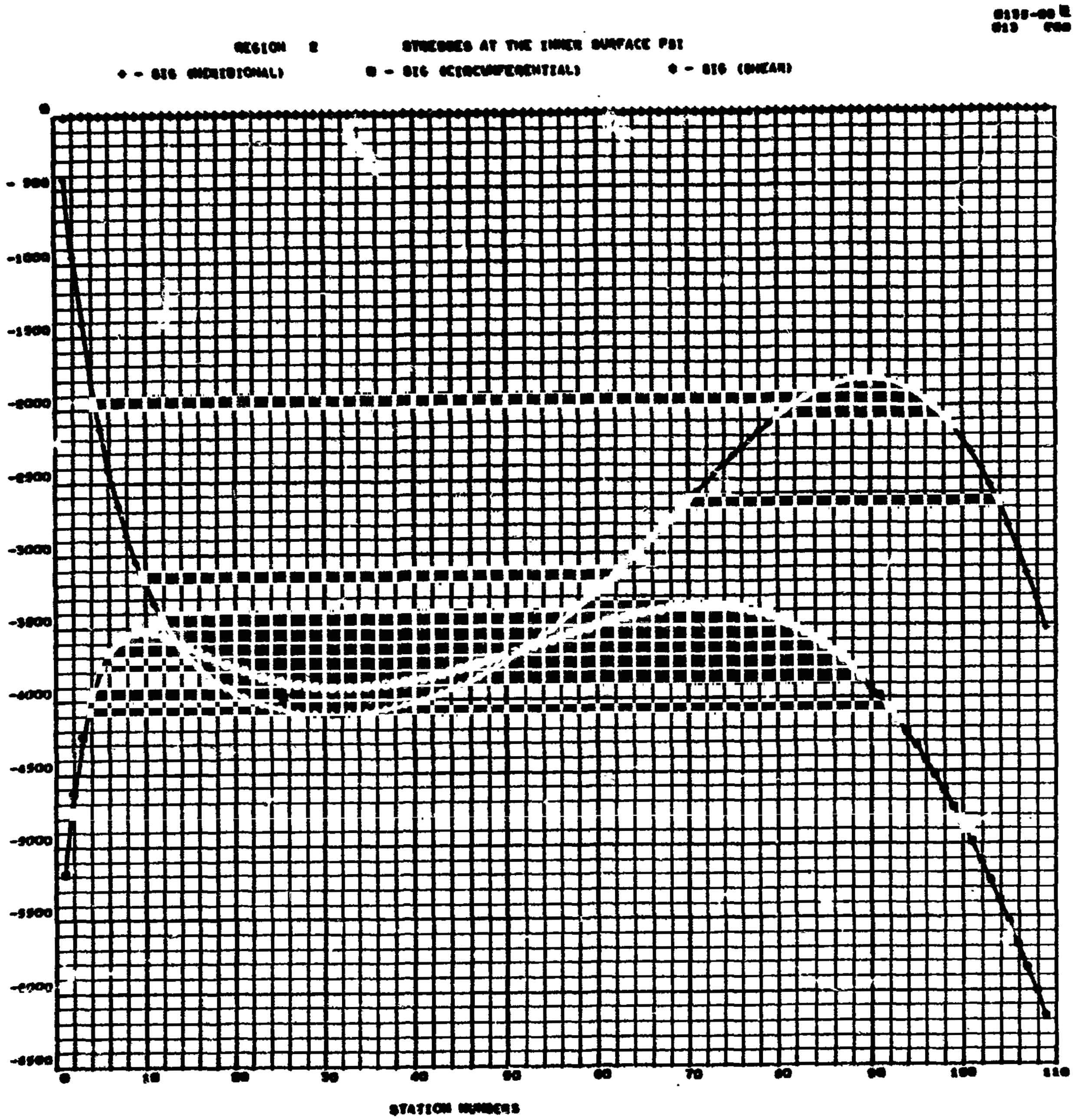
Sample CRT Results (Cont)



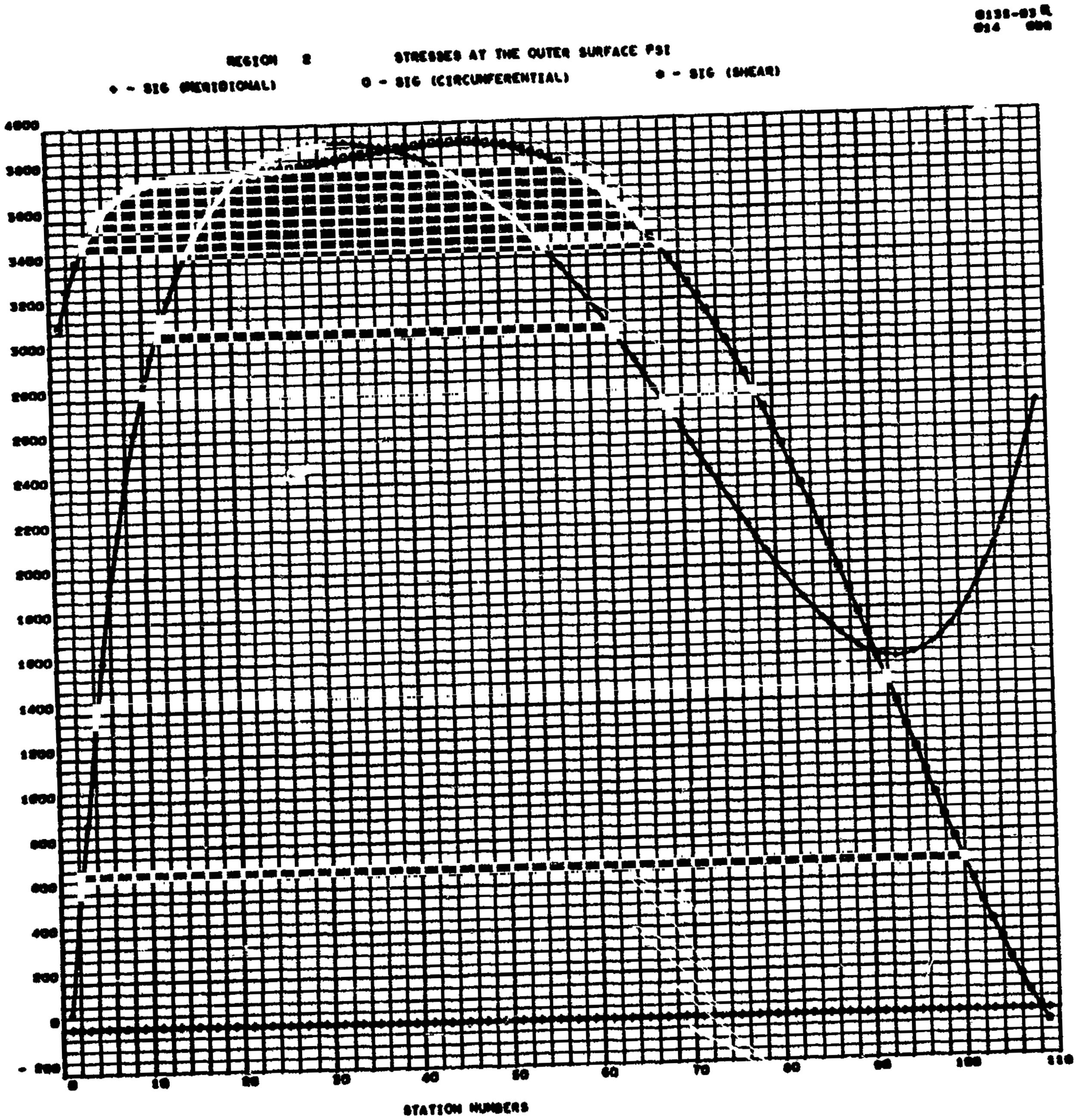
Sample CRT Results (Cont)



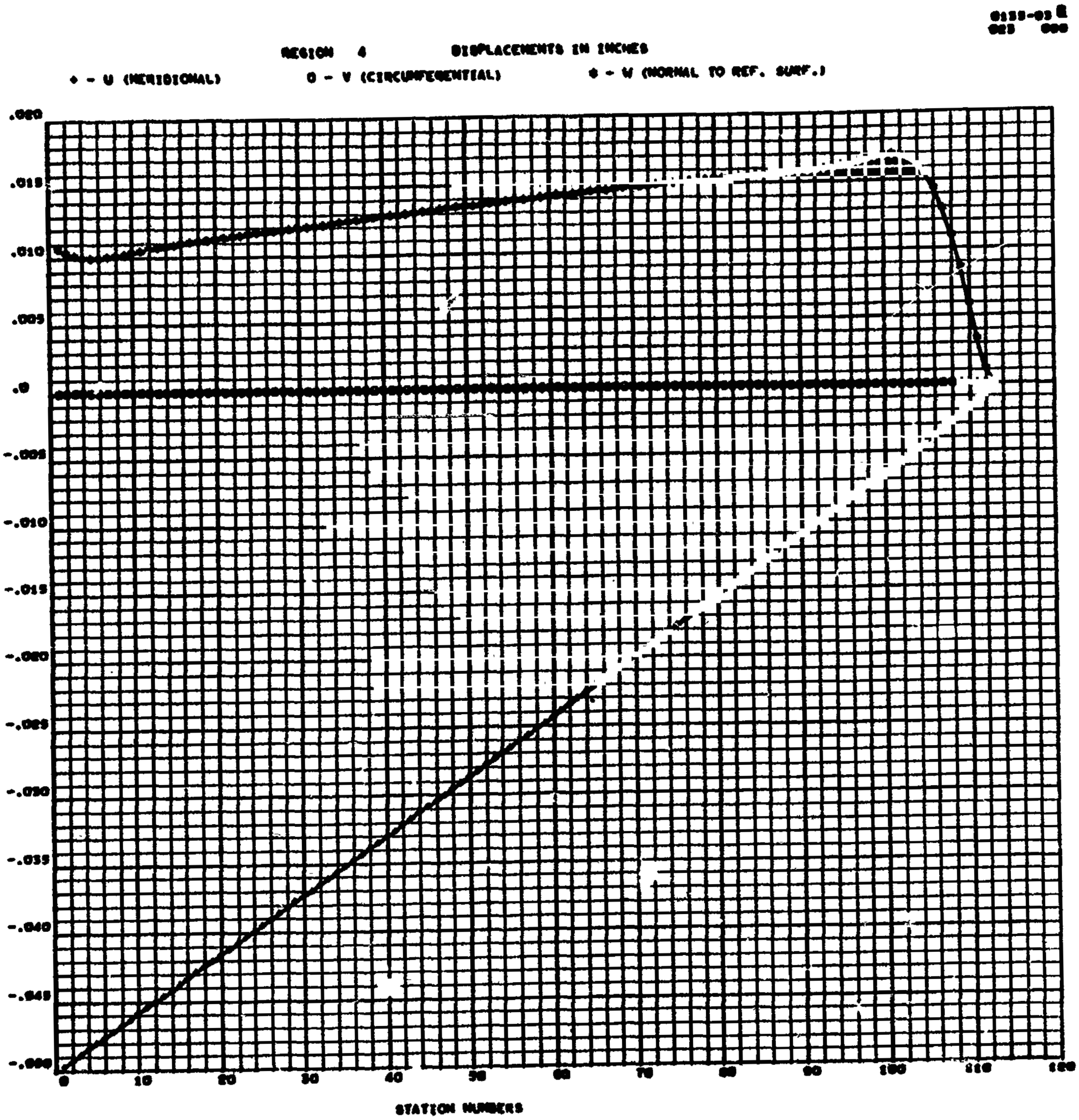
Sample CRT Results (Cont)



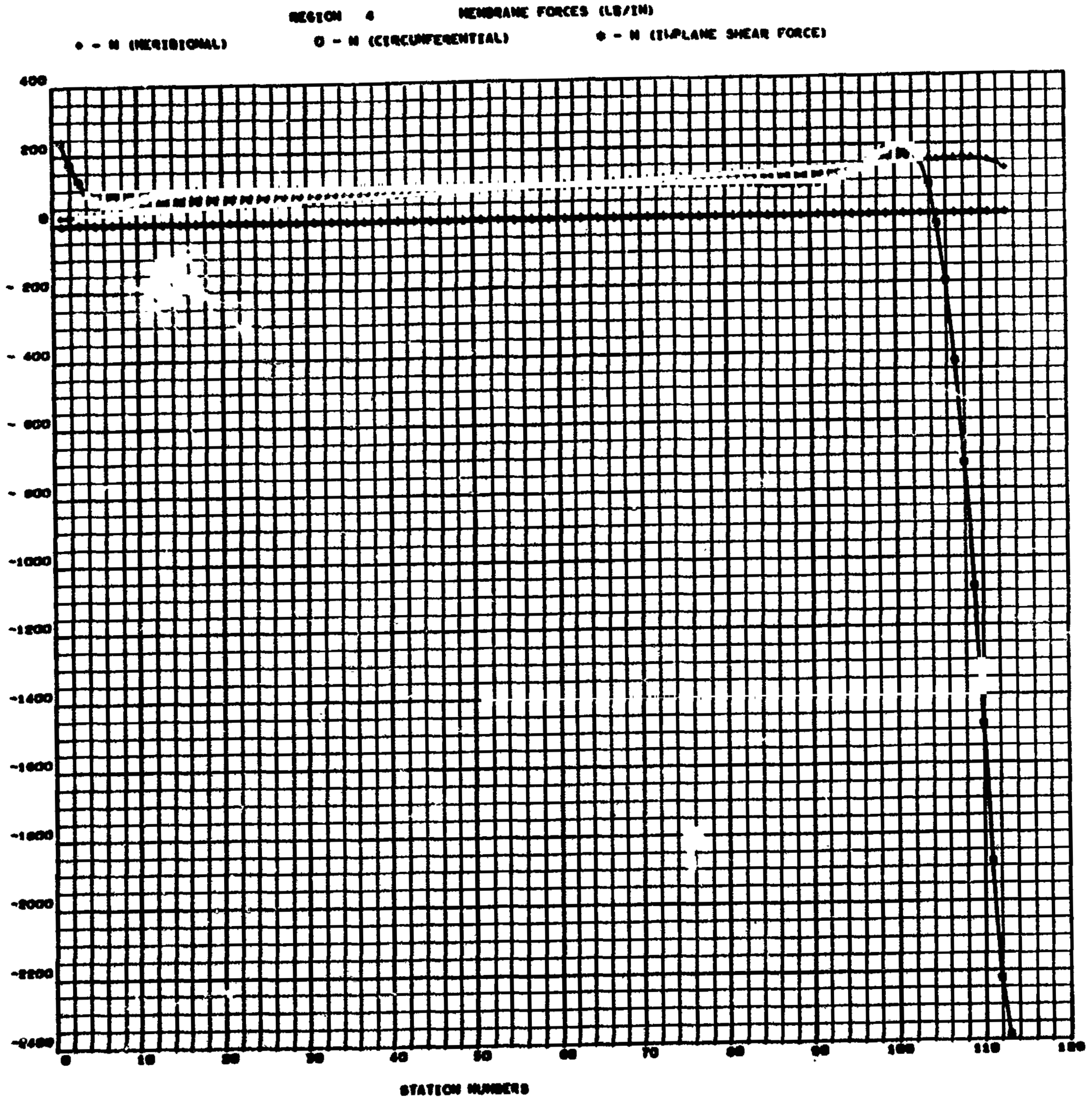
Sample CRT Results (Cont)



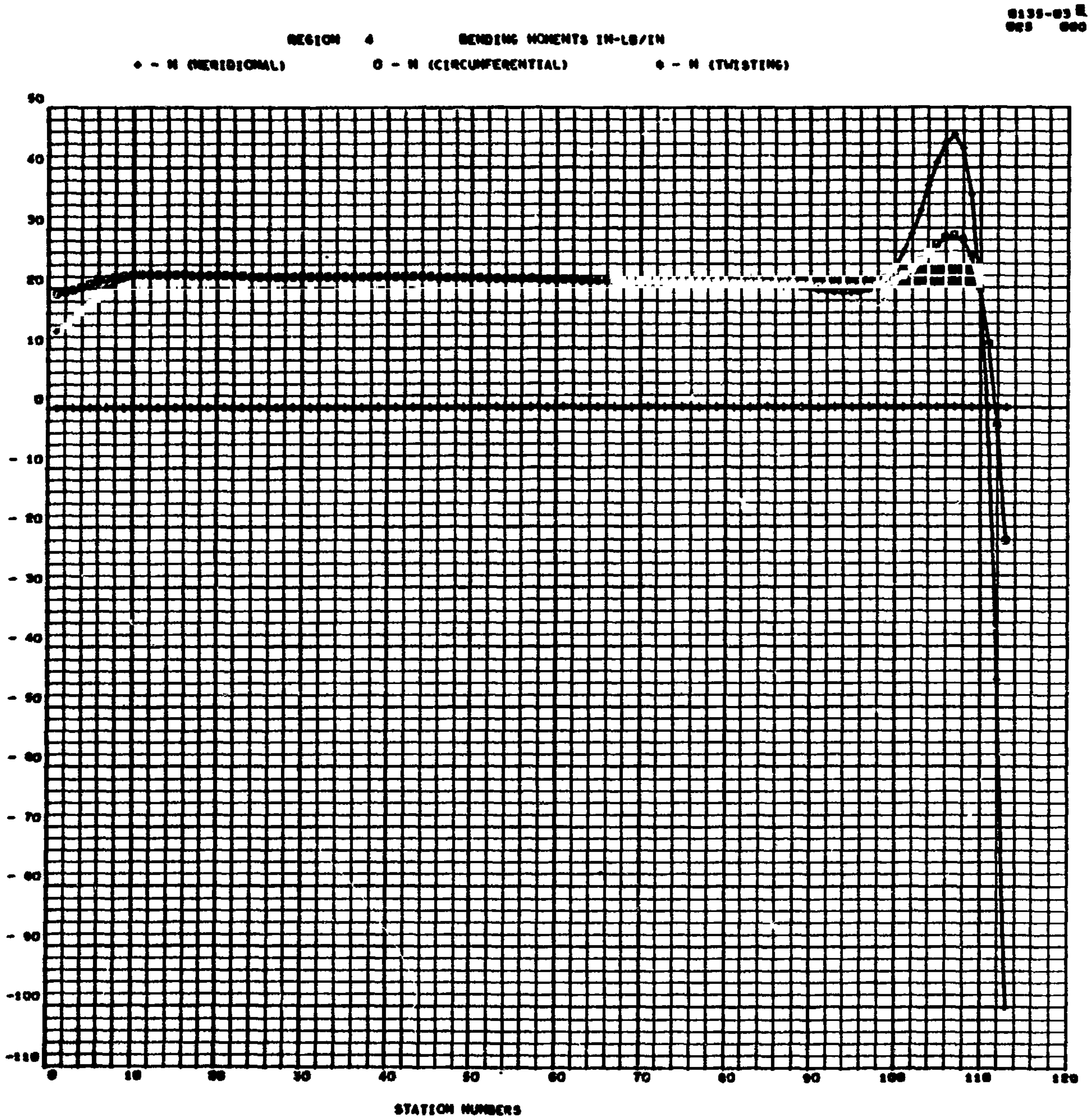
Sample CRT Results (Cont)



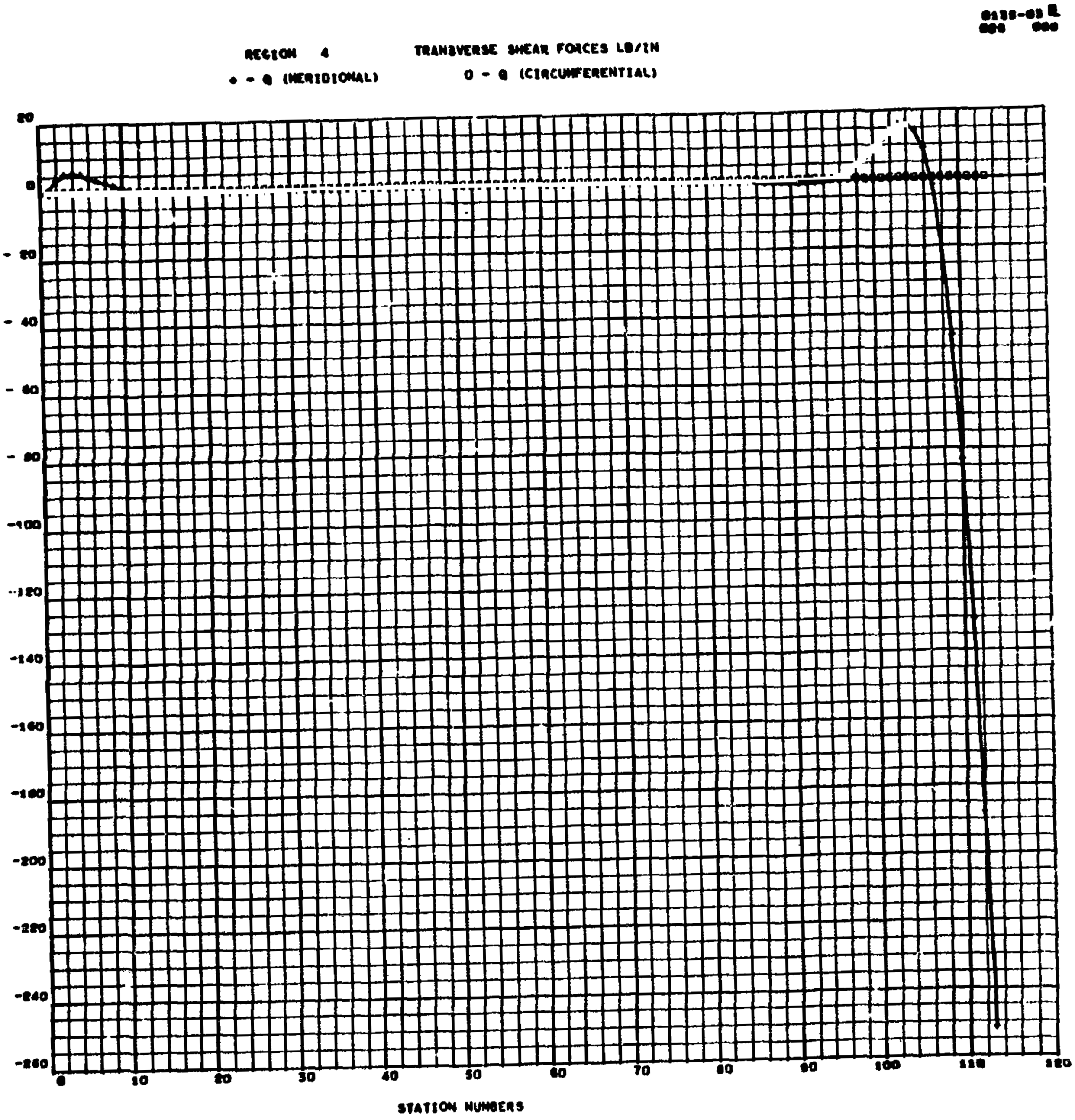
Sample CRT Results (Cont)



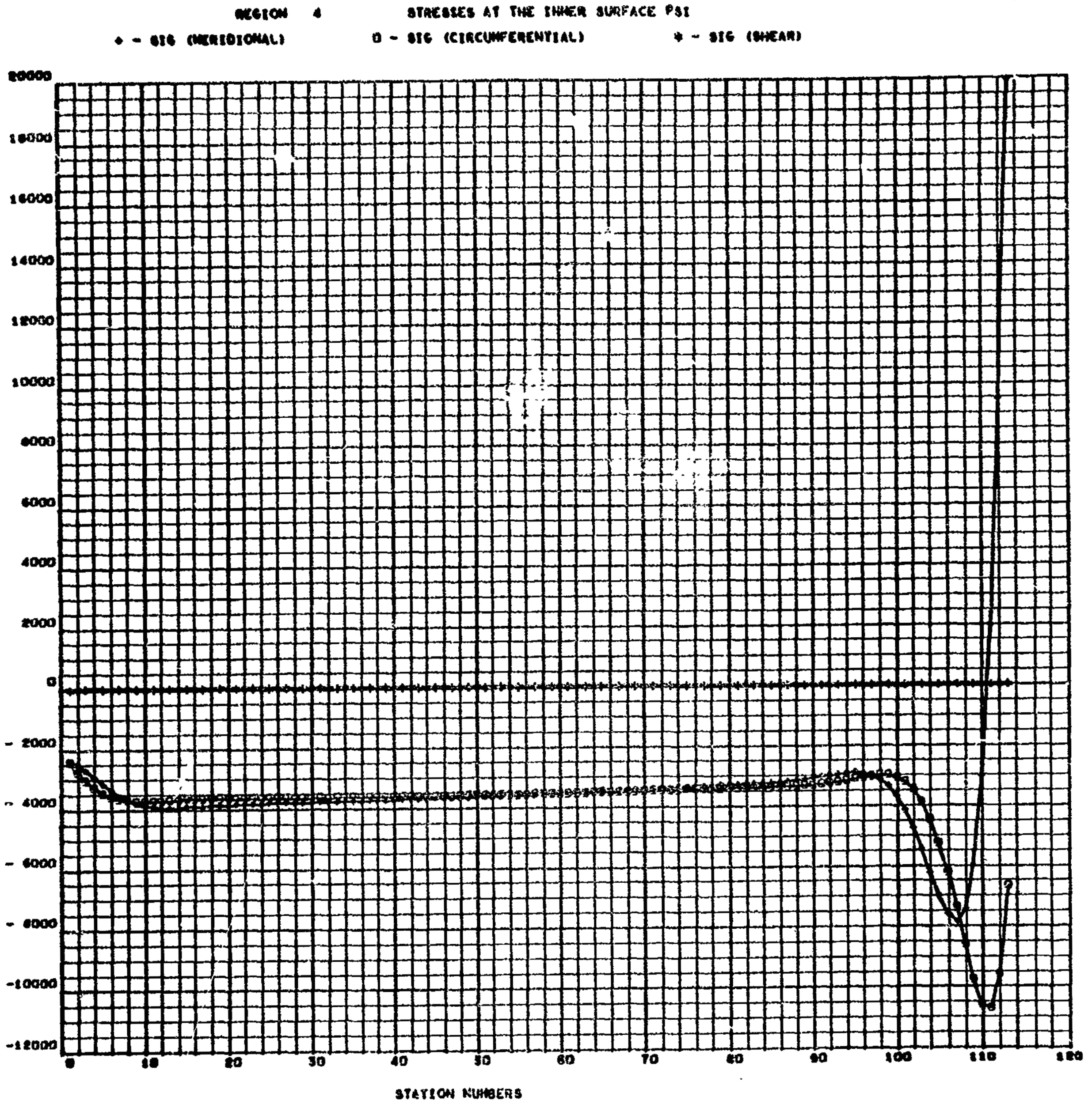
Sample CRT Results (Cont)



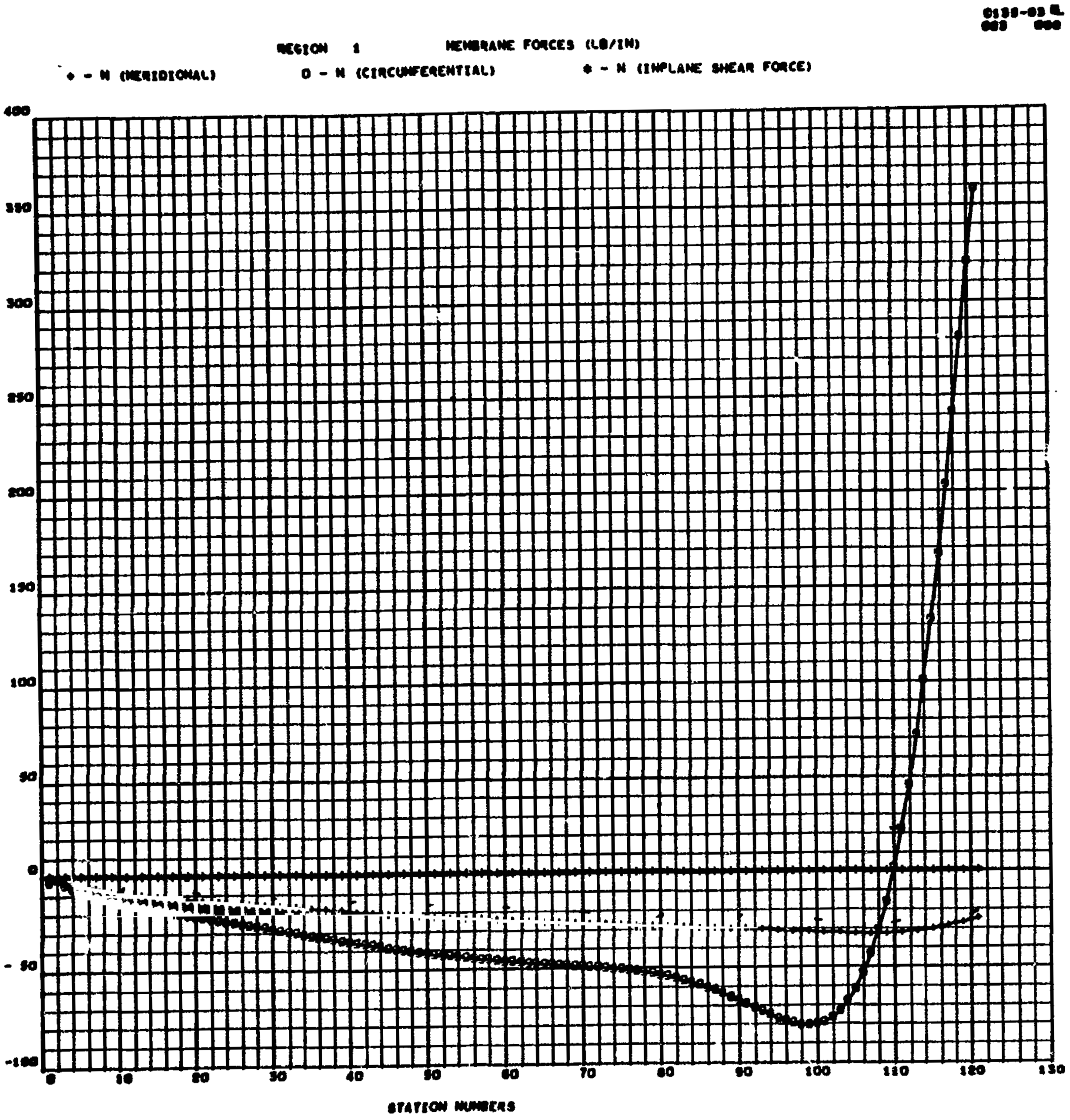
Sample CRT Results (Cont)



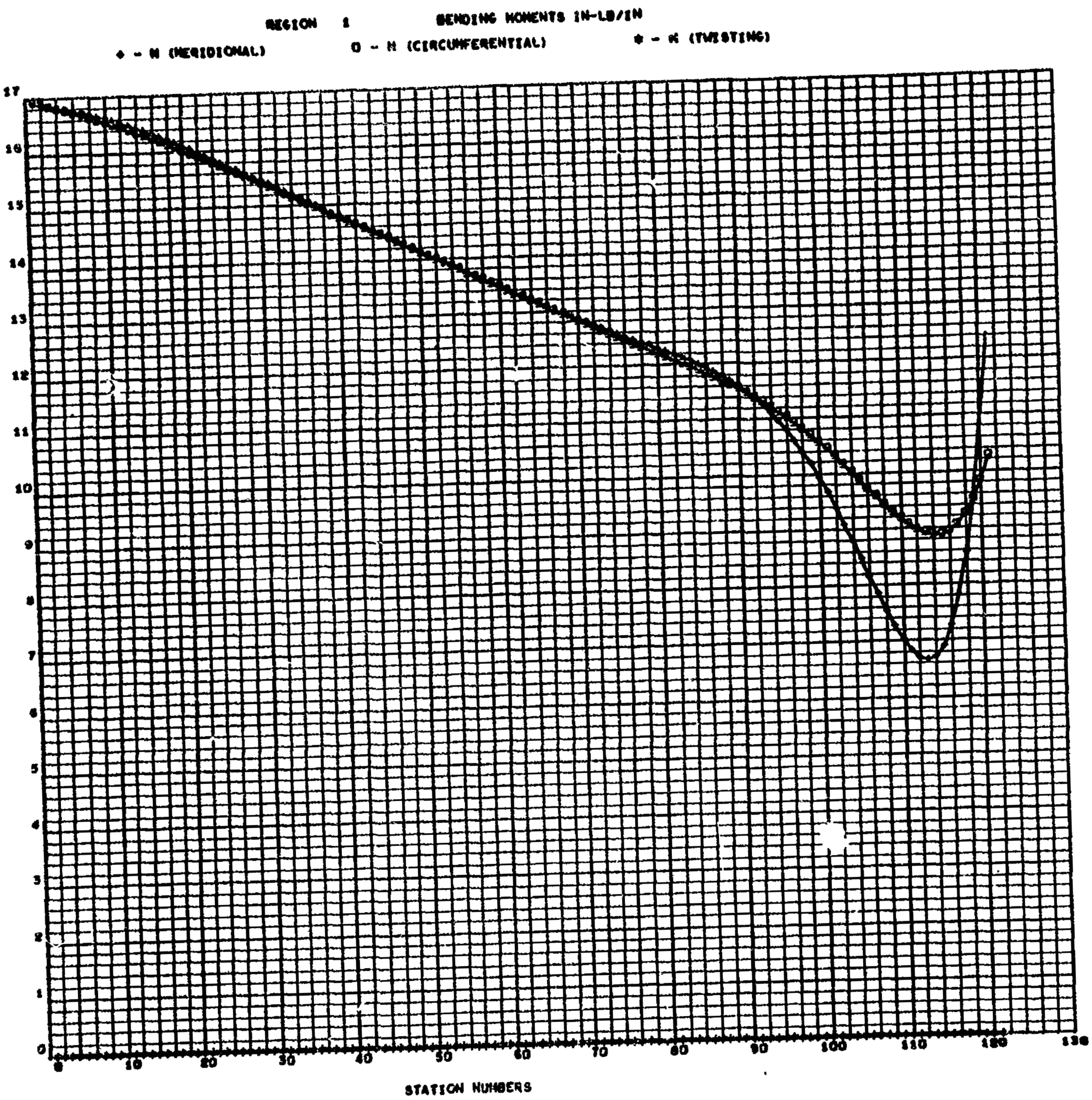
Sample CRT Results (Cont)



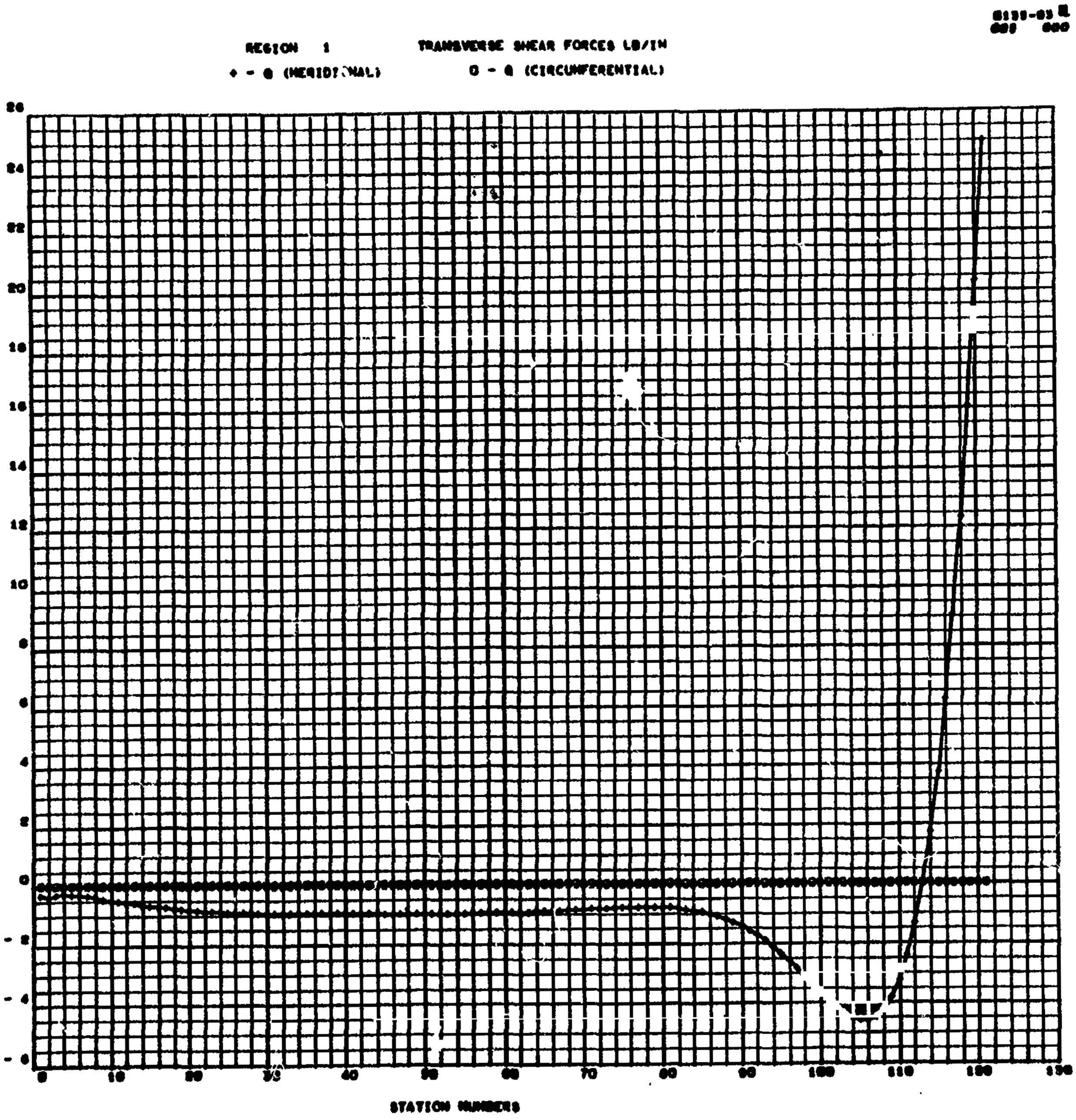
Sample CRT Results (Cont)



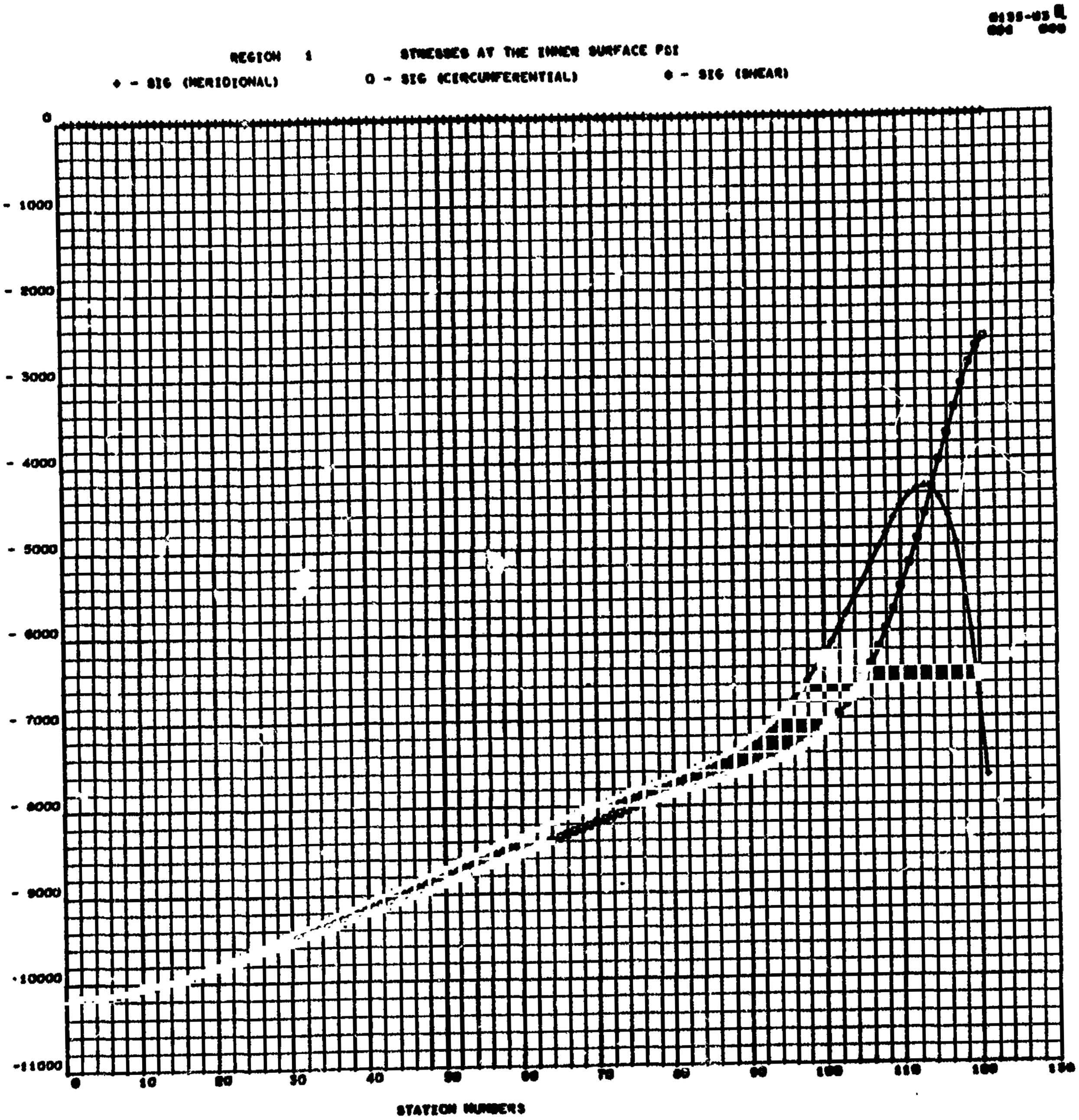
Sample CRT Results (Cont)



Sample CRT Results (Cont)



Sample CRT Results (Cont)



Sample CRT Results (Cont)

The machine printout for region III immediately follows the data sheets. The complete solution (i.e., $n_f = 0$ and 1 combined) is shown for $\theta = 0$ and 90 degrees. To illustrate the graphical plots, results of particular quantities of regions II and IV are shown following printout. Some results for regions I, II were discussed in Section 3.4.5 on output form.

3.7 UTILITY SUBROUTINES

3.7.1 MAD, MSU, MMY, INV

These four subroutines perform matrix addition, subtraction, multiplication, and inversion, respectively. They are extremely simple in their approach and must be recompiled to change dimensions for use in other decks. There are no error indications given other than the usual NAASYS trapping information for underflows, overflows, and divide checks. When data have been entered correctly, these subroutines will present no problems.

3.7.2 DINTRP, ENTERP

These subroutines perform linear double and single interpolation. DINTRP makes use of ENTERP in interpolation for values along a particular curve.

In DINTRP, when the first argument is not bounded by the given table (curves), the statement
"ARGUMENT EXCEEDS EXTENT OF TABLE IN DINTRP."
is printed, followed by
ARGUMENT = (1 PE 12.4)
TABLE VALUES (printed 6/line)
and the job is terminated.

When the argument in the single interpolation subroutine, ENTERP, exceeds the limits of the table, the routine selects the value at either end of the table and continues after printing
"LIMITS OF TABLE EXCEEDED BY ARGUMENT = (1 PE 12.4)
(1 PE 12.4) = VALUE USED FROM TABLE"

Values entered in the tables should always be given in increasing algebraic order, both in terms of the numbers used to designate each curve of the family, and the values assigned to the points along the curve.

3.7.3 CODIMA

CODIMA is a curve-fitting subroutine has the following properties:

1. To the straight portions of any curve defined by three points on a straight line, a straight line will be fitted.
2. To the smooth portion of any curve, a smooth curve will be fitted.
3. The method maintains continuous first derivative except at the ends of a straight segment.
4. The method will fit curves with "corners" or "sharp turns" without the large deviation usually found in other methods.

An interpolation method is developed in such a way that some of the considerations taken when an engineer fits a curve with a french curve are formulated. This is the CODIM (controlled deviation interpolation method) concept.

The method will interpolate in a more engineering manner in the following respects:

1. The first derivative is continuous except at the ends of straight segments defined by three points on a straight line.
2. No large deviation will be found when slope changes are large.
3. Ability to change value and slope rapidly.
4. Ability to fit straight lines on straight line portions of the curve and fit smooth arcs through the smooth portions of the curve.

The method fits a polynomial through an interval with information given by "previous points" (points to the left) and another polynomial through the interval with information given by "subsequent points" (points to the right). These two polynomials are then compared for compatibility. If they differ, a weighted average of the polynomials is taken in such a way that the polynomial that deviates less from the straight line connecting the points defining the interval is given more weight. For simplicity, parabolas are used over higher-degree polynomials in the CODIMA version.

3.7.4 STCOMP

STCOMP is used to combine the station numbers at which the thicknesses are entered in the DAL data region with the station numbers for the inner and outer layer temperatures (set up in DATLDS) to form a common set of stations to be used in the computations for DNAX, D, EK, ENT, and EMT.

3.7.5 CRTG

CRTG is a system of subprograms (some MAP compiled) designed to enable a FORTRAN programmer to use the S-C 4020 CRT plotter for graphing the types most frequently required in engineering and scientific applications.

The output is intended to be imitative of the results obtainable by hand plotting on standard graph paper. Printed and graphical output may be intermixed in any amount.

The system establishes a fairly natural correspondence between the programmer's representation of data and its appearance on the graph. A simple curve may be produced with one CALL statement. For complicated graphs, the full power of FORTRAN may be used to describe the data. Scaling is automatic and includes all curves on a graph.

The drawing of grids and placement of output on the frame are automatic.

Some restrictions of CRTG are as follows:

1. Requires an S-C 4020 to process the output
2. Requires NAASYS and the NAASYS library routines for the S-C 4020
3. Uses the system CRT file, 'UNIT16'
4. Requires the use of nonstandard RETURN statements, a language feature introduced with 7090/7094 FORTRAN IV, Version 13
5. CRTG will fail to express applications that require unusual grids.
6. A special version of NAASYS library routine DXDYV is required. This is included in the deck.

3.8 ERROR INDICATIONS, PITFALLS, RECOMMENDATIONS

Several of the error indications resulting from improper data input have already been discussed. To reiterate, they were as follows:

1. A bad index on a DECRD card (Section 3.4.2)

2. Omission of the negative sign on the last card of a data array (Section 3. 4. 2).

3. Omission of some or all of the title cards (Section 3. 4. 4)

4. Limits of pressure or temperature tables exceeded by arguments when using the indicator = 3 option (Section 3. 4. 7. 1).

One should be very careful to check the output from the program to see that it corresponds to the input that he entered. Better yet, an independent check of input data may prevent a wasted run on the machine. In addition to the four errors indicated above, such things as sign convention, angle measurements, and compatibility of units are common pitfalls.

```
$IBFTC 148RR                                                                     00000002
C  SHELLS OF REVOLUTION                                     DECK NO. 6J-148     00000003
C     W/ ECCENTRIC DISCONTINUITIES AND BRANCHING                                00000004
C                                                                               00000008
C     RESPONSIBLE ENGINEER  AND PROGRAMMER                                      00000009
C        A. P. CAPPELLI        S. C. FURUIKE                                    00000010
C                                                                               00000020
C     REFERENCE  ** AIAA JOURNAL, VOL. 1, NO. 8, AUGUST 1963, PG.1833FF         00000030
C                   AND VOL. 2, NO. 3, MARCH 1964, PG. 590FF                    00000031
C                   ALSO NAA(SID) STR'S 134, 136, 141                           00000032
C                                                                               00000049
C   DATA NOMENCLATURE **                                                        00000050
C                                                     L = UNIT OF LENGTH        00000051
C                                                     P = UNIT OF FORCE         00000052
C     EKK        NO. OF  REGIONS                                                00000060
C     AO         REFERENCE LENGTH (L)                                           00000070
C     HO         REFERENCE THICKNESS (L)                                        00000080
C     EO         REFERENCE YOUNGS MODULUS (P/L**2)                              00000090
C     SIGO       REFERENCE STRESS (P/L**2)                                      00000100
C     PIXI       CRT INDICATOR   PLOTS CURVE WHEN NON-ZERO                      00000120
C     PTHI       PATH IND. *FIRST CASE ALWAYS = 0,NORMAL, *OTHERS MAY =         00000135
C                -,SKIP GEOM, OR =+,CHANGE PRESSURE OR TEMPERATURE LDS.         00000136
C     SUM        NON-ZERO FOR MULTIPLE FOURIER COMPONENTS                       00000140
C                + = SUMMING, WITH PRINTS AT ENFOR VALUES                        00000141
C                - = DISCRETE FOURIER VALUES, PRINTED EA. TIME, NO CRT          00000142
C     ENFO       INITIAL FOURIER COMPONENT                                      00000143
C     ENFI(I)    SUBSEQUENT FOURIER COMPONENTS                                  00000144
C     ENFOR(I)   FOURIER COMPONENT PRINT VALUES.    (THREE PERMITTED)           00000145
C     THETA(I)   HORIZONTAL ANGLE (DEGREES)     TEN MAXIMUM                     00000150
C                                                                               00000179
C   TAPE USAGE  **                                                              00000180
C         7      PROGRAM OVERLAY (TRY DISKS WHERE AVAILABLE)                    00000181
C         3      P AND X MATRICES                                               00000182
C         4      SECTION PROPERTIES DATA                                        00000183
C        3,8     FOURIER COMPONENTS                                             00000184
C        9,10    SUMMING TAPES                                                  00000185
C       12,13    DATA AND GEOMETRY  /REGION                                     00000186
C        11      FOURIER SERIES LOADS TAPE                                      00000187
C                                                                               00000190
C                                                                               00000380
C  ** WHEN THETA = -1.E+10, ENF IS TESTED.  UNTIL ENF = -1.E+10, THE            00000390
C        DATLDS, PANDX, INTLD AND SUMS SUBROUTINES ARE REPEATED.  TWO           00000391
C        INTERMEDIATE PRINTS OF THE FOURIER SUMMING ARE POSSIBLE FOR            00000392
```

```
C         CHECKING CONVERGENCE.  WHEN ENF = -1.E+10 THE PROGRAM MULTIPLIES00000393
C         THE FINAL FOURIER SUMS BY THE COEFFICIENTS, PRINTS THE VALUES   00000394
C         FOR EACH THETA AND PLOTS RESULTS ON NON-ZERO INDICATOR, PIXI.   00000395
C                                                                         00000410
      DIMENSION     BCD(36), ENFOR(4), THETA(11), ENFI(11)                00000420
C                                                                         00000540
      EQUIVALENCE       (DA(1),  EKK  ),(DA(2),   AO    ),(DA(3),  HO    ),00000550
     1(DA(4),   EO    ),(DA(5),  SIGO ),(DA(6),  PIXI   ),(DA(7), PTHI   ),00000551
     2(DA(8),  SUM    ),(DA(9),  ENFO ),(DA(10), ENFI   ),(DA(21), ENFOR),00000552
     3(DA(23), THETA )                                                    00000553
C                                                                         00000640
      COMMON     DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,      00000650
     1 KKE, SQ3; SQ4, SQ6, ENF, IFR, KLM                                  00000651
      COMMON    SDA(3098)                                                 00000652
C                                               ZERO SELECTED DATA AREAS  00000659
      DO  2        I = 1,3148                                             00000660
    2 DA(I)   =   0.0                                                     00000661
C                                                                         00000698
C      ENFI, PTHI, ENFOR AND THETA VALUES MUST BE READ FOR EA. CASE       00000701
    1 DO    3       I = 10,35                                             00000702
    3 DA(I)   =   -1.E+10                                                 00000703
C                                            READ 3 CARDS OF TITLE DATA   00000749
    5 READ    (5,20)   BCD                                                00000750
   20 FORMAT( 12A6 )                                                      00000751
      WRITE   (6,21)   BCD                                                00000752
   21 FORMAT(1H1 /(18X, 12A6 //) )                                        00000753
C                                        INITIALIZE SUM TAPES, INDICATORS 00000759
      NTPW   =   9                                                        00000760
      NTPR   =   10                                                       00000761
      SL2   =  -1.                                                        00000762
      IFR   =   1                                                         00000763
      KLM   =   0                                                         00000764
      PTHI   =   0.                                                       00000765
      THETA   =   0.                                                      00000766
C                                                     READ GENERAL DATA   00000769
   30 CALL   DECRD ( DA )                                                 00000770
C                                                                         00000771
      IF(PTHI .NE. 0.)   GO TO 31                                         00000772
      KTPR   =   13                                                       00000773
      KTPW   =   12                                                       00000774
   31 ENF   =   ENFO                                                      00000782
      IF(SUM .GT. 0.) GO TO 32                                            00000783
      ENFOR   =   ENFO                                                    00000784
```

Shells of Revolution (Cont)

```
      ENFI(11)  =   -1.E+10                                           00000785
      GO  TO  34                                                      00000786
   32 ENFOR(4)  =   -1.E+10                                           00000787
      THETA(11)  =   -1.E+10                                          00000788
   34 WRITE (6, 36)  EKK, ENFO, ENFI, THETA, AO, HO, EO, SIGO, SUM,   00000789
     1 PIXI, PTHI, ENFOR                                              00000790
   36 FORMAT  (1H1, 49X,12HGENERA' DATA////7X,30HNO. OF SHELL REGIONS (E00000791
     1KK)  = ,1PE13.4/// 7X,30HFOURIER COMPONENTS (ENFI)   - // 24X,  00000792
     2 6E13.4/24X, 6E13.4/// 7X,24HPRINT ANGLES (THETA)   - //24X,    00000793
     3 6E13.4/24X, 5E13.4/// 7X,14HCONSTANTS   - ,// 7X,7HAO    =,E13.4,00000794
     4 4X,7HHO    =,E13.4, 4X,7HEO     =,E13.4, 4X,7HSIGO  =,E13.4 //7X, 00000795
     5 7HSUM    =,E13.4, 4X,7HPIXI  =,E13.4, 4X,7HPTHI  =E13.4// 7X,    00000796
     6 22HPRINT ENFS (ENFOR)   -//24X, 4E13.4/ 1H8, 24X, 62H(FLAG -1.0E+00000797
     710 INDICATES LAST ENFI, ENFOR, AND THETA VALUES.) )             00000798
C                                                                     00000799
   38 REWIND  NTPW                                                    00000800
      REWIND  KTPW                                                    00000801
      REWIND  NTPR                                                    00000802
      REWIND  KTPR                                                    00000803
      REWIND  8                                                       00000804
      REWIND  11                                                      00000805
      REWIND  3                                                       00000806
      REWIND  4                                                       00000807
      SQ3   =   AO * SIGO /EO                                         00000810
      SQ4   =   SIGO * HO **3 /AO                                     00000811
      SQ6   =   SIGO * HO                                             00000812
      ELAM2 = (HO /AO) **2                                            00000820
C                                     READ DATA AND SET UP GEOM. /REG. 00000839
      KKE   =   EKK                                                   00000840
   50 CALL  DATLNK                                                    00000860
      WRITE  (KTPW)  S1                                               00000881
      REWIND  KTPW                                                    00000882
C                                             FORM P AND X MATRICES   00000889
      CALL  PANDX                                                     00000890
C                                     DEFLECTIONS AND INTERNAL LDS00000899
      CALL  INTLD                                                     00000900
C                                                    FOURIER SUMS     00000919
      CALL  SUMS                                                      00000920
      IF(SUM .EQ. 0.)  GO TO 60                                       00000925
      IF ( ENF )  60,38,38                                            00000930
C                                                    PLOT RESULTS     00000939
   60 IF (PIXI)   70,1,70                                             00000940
   70 REWIND  NTPW                                                    00000950
```

Shells of Revolution (Cont)

```
      CALL  PIX
      GO  TO  1
      END
```

Shells of Revolution (Cont)

```
$IBFTC MADD
C     MATRIX ADD SUBROUTINE                                    DECK NO. 8K-903   00000400
C                                                                                     410
C  ARGUMENTS                                                                          420
C     L  NO. OF ROWS                                                                  430
C     M  NO. OF COLS                                                                  440
C     A(I.J)      MRA                                                                 450
C     B(I.J)      MAD                                                                 460
C     C(I.J)      MSR                                                                 470
      SUBROUTINE MAD(L.M.A.B.C)                                                       480
      DIMENSION   A(4,4), B(4.4). C(4.4)                                              490
      DO 30 I=1.L                                                                     500
      DO 30 J=1.M                                                                     510
   30 C(I.J)=A(I.J)+B(I.J)                                                            520
      RETURN                                                                          530
      END
```

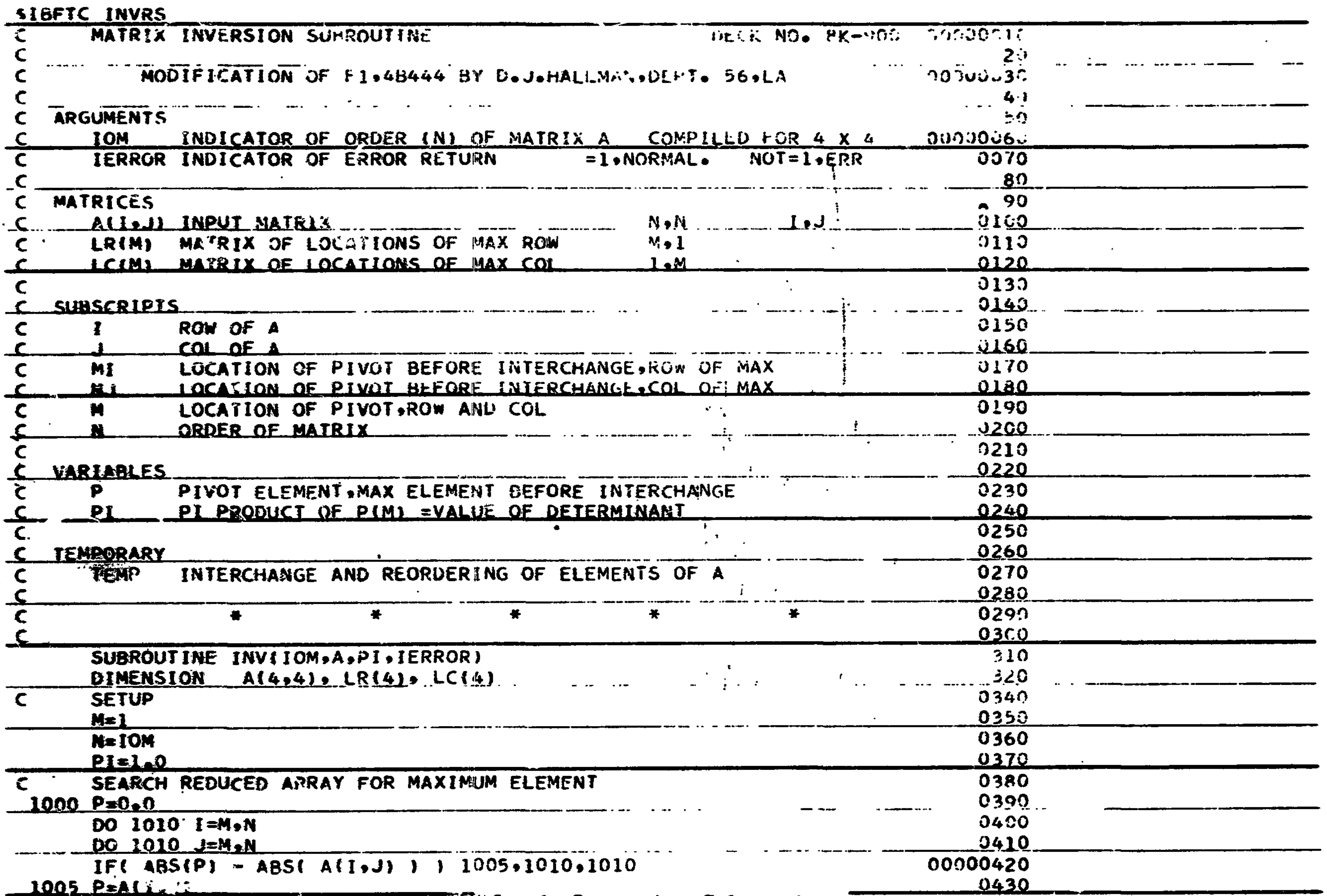
Matrix Add Subroutine

```
$IBFTC MSUR                                           DECK NO. 8K-904 00000400
C      MATRIX SUBTRACT SUBROUTINE                                          410
C                                                                          420
C  ARGUMENTS                                                               430
C      L  NO. OF ROWS                                                      440
C      M  NO. OF COLS                                                      450
C      A(I,J)    MRA                                                       460
C      B(I,J)    MSU                                                       470
C      C(I,J)    MSR                                                       480
       SUBROUTINE MSU(L,M,A,B,C)                                      0 0  490
       DIMENSION   A(4,4), B(4,4), C(4,4)                                  500
       DO 30 I=1,L                                                         510
       DO 30 J=1,M                                                         520
   30 C(I,J)=A(I,J)-B(I,J)                                                 530
       RETURN
       END
```

Matrix Subtract Subroutine

```
$IBFTC MMPY
C     MATRIX MULTIPLY SUBROUTINE                           DECK NO. 8K-901
C
C  ARGUMENTS
C     L  NO. OF ROWS X MATRIX
C     M  NO. OF COLS X MATRIX
C     N  NO. OF COLS Y MATRIX
C     X(I,K)    MRA
C     Y(K,J)    MMY
C     Z(I,J)    MSR
      SUBROUTINE MMY(L,M,N,X,Y,Z)
      DIMENSION   X(4,4), Y(4,4), Z(4,4)
      DO 30 I=1,L
      DO 30 J=1,N
      Z(I,J)=0.0
      DO 30 K=1,M
   30 Z(I,J)=Z(I,J)+X(I,K)*Y(K,J)
      RETURN
      END
```

Matrix Multiply Subroutine



```
$IBFTC INVRS
C     MATRIX INVERSION SUBROUTINE                       DECK NO• PK-900  00000010
C                                                                             20
C        MODIFICATION OF F1•4B444 BY D•J•HALLMAN•DEPT• 56•LA             00000030
C                                                                             40
C  ARGUMENTS                                                                  50
C     IOM    INDICATOR OF ORDER (N) OF MATRIX A   COMPILED FOR 4 X 4    00000060
C     IERROR INDICATOR OF ERROR RETURN       =1•NORMAL•   NOT=1•ERR         0070
C                                                                             80
C  MATRICES                                                                   90
C     A(I•J) INPUT MATRIX                     N•N        I•J                0100
C     LR(M)  MATRIX OF LOCATIONS OF MAX ROW   M•1                           0110
C     LC(M)  MATRIX OF LOCATIONS OF MAX COL   1•M                           0120
C                                                                           0130
C  SUBSCRIPTS                                                               0140
C     I      ROW OF A                                                       0150
C     J      COL OF A                                                       0160
C     MI     LOCATION OF PIVOT BEFORE INTERCHANGE•ROW OF MAX                0170
C     MJ     LOCATION OF PIVOT BEFORE INTERCHANGE•COL OF MAX                0180
C     M      LOCATION OF PIVOT•ROW AND COL                                  0190
C     N      ORDER OF MATRIX                                                0200
C                                                                           0210
C  VARIABLES                                                                0220
C     P      PIVOT ELEMENT•MAX ELEMENT BEFORE INTERCHANGE                   0230
C     PI     PI PRODUCT OF P(M) =VALUE OF DETERMINANT                       0240
C                                                                           0250
C  TEMPORARY                                                                0260
C     TEMP   INTERCHANGE AND REORDERING OF ELEMENTS OF A                    0270
C                                                                           0280
C                 *          *          *          *          *             0290
C                                                                           0300
      SUBROUTINE INV(IOM•A•PI•IERROR)                                        310
      DIMENSION   A(4•4)• LR(4)• LC(4)                                       320
C     SETUP                                                                 0340
      M=1                                                                   0350
      N=IOM                                                                 0360
      PI=1•0                                                                0370
C     SEARCH REDUCED ARRAY FOR MAXIMUM ELEMENT                              0380
 1000 P=0•0                                                                 0390
      DO 1010 I=M•N                                                         0400
      DO 1010 J=M•N                                                         0410
      IF( ABS(P) - ABS( A(I•J) ) ) 1005•1010•1010                       00000420
 1005 P=A(I•J)                                                              0430
```

Matrix Inversion Subroutine

```
      MI=I                                                  0440
      MJ=J                                                  0450
 1010 CONTINUE                                              0460
      LR(M)=MI                                              0470
      LC(M)=MJ                                              0480
C     INTERCHANGE MAXIMUM ROW WITH PIVOT ROW                0490
 2000 IF(MI-M)2100,2200,2100                                0500
 2100 DO 2110 J=1,N                                         0510
      TEMP=A(MI,J)                                          0520
      A(MI,J)=-A(M,J)                                       0530
 2110 A(M,J)=TEMP                                           0540
C     INTERCHANGE MAXIMUM COL WITH PIVOT COL                0550
 2200 IF(MJ-M)2205,3000,2205                                0560
 2205 DO 2210 I=1,N                                         0570
      TEMP=A(I,MJ)                                          0580
      A(I,MJ)=-A(I,M)                                       0590
 2210 A(I,M)=TEMP                                           0600
C     DIVIDE PIVOT COL BY PIVOT ELEMENT                     0610
 3000 DO 3010 I=1,N                                         0620
      IF(I-M)3005,3010,3005                                 0630
 3005 A(I,M)=-A(I,M)/P                                      0640
 3010 CONTINUE                                              0650
C     ELIMINATE                                             0660
 4000 DO 4210 I=1,N                                         0670
      IF(I-M)4005,4210,4005                                 0680
 4005 DO 4110 J=1,N                                         0690
      IF(J-M)4105,4110,4105                                 0700
 4105 A(I,J)=A(I,M)*A(M,J)+A(I,J)                           0710
 4110 CONTINUE                                              0720
 4210 CONTINUE                                              0730
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT                     0740
 5000 DO 5010 J=1,N                                         0750
      IF(J-M)5005,5010,5005                                 0760
 5005 A(M,J)=A(M,J)/P                                       0770
 5010 CONTINUE                                              0780
C     FORM DETERMINANT                                      0790
      PI=P*PI                                               0800
      A(M,M)=1.0/P                                          0810
      M=M+1                                                 0820
      IF(M-N)1000,5020,5999                                 0830
 5020 P=A(M,M)                                              0840
      GO TO 3000                                            0850
 5999 M=N-1                                                 0860
```

Matrix Inversion Subroutine (Cont)

```
                                                                   0870
 6000 MI=LC(M)                                                     0880
      MJ=LR(M)                                                     0890
C     RE-ORDER ROWS OF INVERSE                                     0900
      IF(MI-M)6005,6200,6005                                       0910
 6005 DO 6010 J=1,N                                                0920
      TFMP=A(M,J)                                                  0930
      A(M,J)=-A(MI,J)                                              0940
 6010 A(MI,J)=TEMP                                                 0950
C     RE ORDER COLS OF INVERSF                                     0960
 6200 IF(MJ-M)6205,7000,6205                                       0970
 6205 DO 6210 I=1,N                                                0980
      TEMP=A(I,M)                                                  0990
      A(I,M)=-A(I,MJ)                                              1000
 6210 A(I,MJ)=TEMP                                                 1010
 7000 M=M-1                                                        1020
      IF(M)9002,9001,6000                                          1030
 9001 IERROR=1                                                     1040
      GO TO 9999                                                   1050
C     M IS LESS THAN ZERO                                          1060
 9002 IERROR=2                                                     1080
 9999 RETURN                                                       2030
              FND
```

Matrix Inversion Subroutine (Cont)

```
$IBFTC CF3P                                                             CODIM000
C     PARABOLIC CURVE FITTING SUBROUTINE  (THREE POINTS)                CODIM001
C                                                                       CODIM009
      SUBROUTINE CODIMA (N1, X, Y, XI, YI, N2, SHAPE)                   CODIM010
C                                                                       CODIM011
C  ARGUMENTS                                                            CODIM012
C     N1          NO. OF POINTS TO ITERPOLATE                           CODIM013
C     X           LOCATION OF POINTS TO BE INTERPOLATED                 CODIM014
C     Y           ANSWERS                                               CODIM015
C     XI          INDEPENDENT ARGUMENT                                  CODIM016
C     YI          DEPENDENT ARGUMENT                                    CODIM017
C     N2          NO. OF ARGUMENTS                                      CODIM018
C     SHAPE       0 = FITS END WITH STRAIGHT LINE   1 = CURVE,LAST 3 PTS.CODIM019
C                                                                       CODIM020
      DIMENSION X(1),Y(1),XI(1),YI(1),D(2),A(2),B(2),C(2)               CODIM025
C                                                                       CODIM029
  100 IN = 0                                                            CODIM030
      XK = SHAPE                                                        CODIM040
C                                                                       CODIM049
      DO 800 N = 1,N1                                                   CODIM050
C                                                                       CODIM059
      IF (N2-2) 110,115,120                                             CODIM060
  110 Y(N) = YI(N2)                                                     CODIM070
      GO TO 800                                                         CODIM080
C                                                                       CODIM089
  115 Y(N) = (YI(2)-YI(1))/(XI(2)-XI(1))*  (X(N)-XI(1))+YI(1)           CODIM090
      GO TO 800                                                         CODIM100
C                                                                       CODIM109
  120 J = 1                                                             CODIM110
  125 IF(XI(J)-X(N)) 130,140,150                                        CODIM120
  140 Y(N) = YI(J)                                                      CODIM130
      GO TO 800                                                         CODIM140
C                                                                       CODIM149
  130 J = J+1                                                           CODIM150
      IF(J-N2) 125,125,145                                              CODIM160
  145 Y(N) = (YI(N2)-YI(N2-1))/(XI(N2)-XI(N2-1))*(X(N)-XI(N2-1))        CODIM170
     1        + YI(N2 - 1)                                              CODIM180
      GO TO 800                                                         CODIM190
C                                                                       CODIM199
  150 IF(J-2) 115,155,160                                               CODIM200
  155 K = 3                                                             CODIM210
      JJ = 1                                                            CODIM220
      GO TO 185                                                         CODIM230
```

Parabolic Curve Fitting Subroutine
(Three Points)

```
160 IF(J-N2) 170,165,145                                          CODIM240
165 K = N2-1                                                      CODIM250
    JJ = 2                                                        CODIM260
    GO TO 185                                                     CODIM270
170 IF(J-IN) 180,300,180                                          CODIM280
180 JJ = 3                                                        CODIM290
    K = J                                                         CODIM300
C                                                                 CODIM309
185 DO 200 M = 1,2                                                CODIM310
    X1 = XI(K-1)-XI(K)                                            CODIM320
    X2 = XI(K)-XI(K-2)                                            CODIM330
    X3 = XI(K-2)-XI(K-1)                                          CODIM340
    Y1 = YI(K-1)-YI(K)                                            CODIM350
    Y2 = YI(K)-YI(K-2)                                            CODIM360
    Y3 = YI(K-2)-YI(K-1)                                          CODIM370
    XX1 = XI(K-2)**2                                              CODIM380
    XX2 = XI(K-1)**2                                              CODIM390
    XX3 = XI(K)**2                                                CODIM400
    D(M) = XX1*X1 +XX2*X2+ XX3*X3                                 CODIM410
    A(M) = (YI(K-2)*X1 +YI(K-1)*X2+ YI(K)*X3)/D(M)                CODIM420
    B(M) = (XX1*Y1 + XX2*Y2+XX3*Y3)/D(M)                          CODIM430
    C(M) = YI(K-2)- A(M)*XX1 -B(M)*XI(K-2)                        CODIM440
200 K = K+1                                                       CODIM450
300 P1 = X(N)*(A(1)*X(N)+B(1)) +C(1)                              CODIM460
    P2 = X(N)*(A(2)*X(N)+B(2)) +C(2)                              CODIM470
    AL = (X(N)-XI(J-1))/(XI(J)-XI(J-1))                           CODIM480
    S  = YI(J)*AL + YI(J-1)*(1.0-AL)                              CODIM490
    GO TO (320,330,350),JJ                                        CODIM500
C                                                                 CODIM509
320 P2 = P1                                                       CODIM510
    AL = (X(N)-XI(1))/(XI(2)-XI(1))                               CODIM520
    S = AL*YI(2) + (1.0-AL)*YI(1)                                 CODIM530
    IF (SHAPE) 321,322, 322                                       CODIM540
321 XM1 = ABS (YI(2) - YI(1)) / (XI(2) - XI(1))                   CODIM550
    XM2 = ABS (YI(3) - YI(2)) / (XI(3) - XI(2))                   CODIM560
    XK = 1. - ABS (XM1 -XM2) / (XM1 + XM2)                        CODIM570
322 P1 = S + XK *(P2-S)                                           CODIM580
    GO TO 350                                                     CODIM590
C                                                                 CODIM599
330 P1 = P2                                                       CODIM600
    AL = (X(N)-XI(N2-1))/ (XI(N2)-XI(N2-1))                       CODIM610
    S = AL* YI(N2) +(1.0-AL)*YI(N2-1)                             CODIM620
    IF (SHAPE) 331,332, 332                                       CODIM630
```

Parabolic Curve Fitting Subroutine
(Three Points) (Cont)

```
  331 XM1 = ABS (YI(N2 - 1) - YI(N2)) /(XI(N2 -1) - XI(N2))                   CODIM640
      XM2 = ABS (YI(N2 -2) - YI(N2 -1)) / (XI(N2 -2) - XI(N2 -1))             CODIM650
      XK = 1. - ABS (XM1 -XM2) / (XM1 + XM2)                                   CODIM660
  332 P2 = S + XK*(P1-S)                                                       CODIM670
C                                                                              CODIM679
  350 E1 = ABS (P1-S)                                                          CODIM680
      E2 = ABS (P2-S)                                                          CODIM690
      IN = J                                                                   CODIM700
      IF(E1+E2) 700,700,750                                                    CODIM710
  700 Y(N) = S                                                                 CODIM720
      GO TO 800                                                                CODIM730
  750 YNUM = E1 * AL * P2 + (1. - AL) * E2 * P1                                CODIM740
      YDEN = E1 * AL + (1. - AL) * E2                                          CODIM750
      Y(N) = YNUM / YDEN                                                       CODIM760
  800 CONTINUE                                                                 CODIM770
C                                                                              CODIM779
  900 RETURN                                                                   CODIM780
      END                                                                      CODIM790
```

Parabolic Curve Fitting Subroutine
(Three Points) (Cont)

```
$IBFTC DLNK                                                             00000001
C        REGIONAL DATA READ SUBROUTINF                    6J-148  ** LINK 1  00000010
C                                                                       00000011
      SUBROUTINF  DATLNK                                                00000012
C                                                                       00000013
C                                                                       00000019
C        DATA MAY BE ENTERED AS CONSTANTS THROUGHOUT (SEE EX BELOW),    00000020
C     AS DISCRETE VALUES, FOURIER SERIES FOR UNSYMMETRICAL LOADS, ETC.  00000021
C     CURVE FITTING, TABLE LOOKUP, OR A COMBINATION OF THESE.           00000022
C                                                                       00000047
C **  NOMENCLATURF FOR SDA DATA  **                                     00000048
C                                                   L = UNIT OF LENGTH  00000049
C                                                   P = UNIT OF FORCE   00000050
C     *FN         NUMBER OF POINTS /RFGION  (150 MAXIMUM)               00000051
C     *GEOMI      GEOMETRY INDICATOR                                    00000052
C     *SPRL       LOCATION OF INTERNAL SUPPORT SPRING                   00000053
C     *UK         SPRING VALUE - PHI DIRECTION                          00000054
C     *VK            * * *     - THETA DIRECTION                        00000055
C     *WK            * * *     - N DIRECTION                            00000056
C     *EMK           * * *     - MOMENT                                 00000057
C     *PSI        DISCONTINUITY ANGLE AT THE END OF THE REGION  (DEGREES)00000058
C     *ECX        FCCFNTRICITY OF REFFRENCE SURFACE AT BOTTOM DISCONT.  00000059
C     *BCIT       BOUNDARY CONDITION INDICATOR, TOP  (-)                00000060
C     *BCIB          * *       * *       * *   , BOTTOM  (+)            00000061
C     *PFLAG      PRINT INDICATOR   NON-ZERO PRINTS ALL INPUT DATA      00000062
C     *STRI       LAYER NO. FOR 2ND STRESS PRINT (OTHER = INNER SURFACE) 00000063
C    **POI        POISSON'S RATIO                                       00000064
C     *DEL        INTERVAL RFTWEEN STATIONS, ARC LENGTH                 00000065
C      EX         CONSTANT DATA INDICATOR. USE ONLY WHEN SUM = 0. ***   00000066
C                 0.=NO CONSTANTS,   -=ALL CONSTANTS,   +1=SECTION PROP. 00000067
C                 AND TENP. LDS.,   +2=SYMMETRICAL PRESSURE LDS., NO TEMP00000068
C            ***  REPEAT ALL DATA FOR MULTIPLE REGIONS OR CASES ***     00000069
C     *TLOC(5)    USED BY DATLDS TO PRESERVE TABLE LOCATION             00000079
C                                                                       00000080
C    **D(I)       MEMBRANE STIFFNESS (DIMENSIONLESS)                    00000081
C    **EK(I)      RENDING STIFFNFSS (DIM)                               00000082
C    **ENT(I)     TEMPERATURE LOAD (DIM)                                00000083
C    **EMT(I)     TEMPERATURF MOMENT                                    00000084
C    **PFE(I)     FOURIER COMPONENT FOR LOAD  -  PHI DIRECTION          00000085
C    **PTH(I)     DITTO     * * *             -  THETA DIRECTION        00000086
C    **PN(I)      DITTO     * * *             -  N DIRECTION            00000087
C    **ET(I)      MODULUS OF ELASTICITY          FOR N SUMMATIONS       00000088
C    **T(I)       TEMPFRATURF CHANGE                  * * DITTO * *     00000089
```

Regional Data Read Subroutine

```
C    **ALF(I)       THERMAL EXPANSION COEFFICIENT        * * DITTO * *      00000090
C    **DNA(I)       DISTANCE FROM NEUTRAL AXIS                              00000091
C     *RHOX(I)      R /AO                                                   00000092
C     *GAMA(I)      RHO' /RHOX                                              00000093
C     *R(I)         DISTANCE FROM AXIS (L)     COMPUTED IN GEOM SUBROUTINE  00000094
C     *WTHD(I)      NON-DIMENSIONAL CURVATURE - THETA DIRECTION             00000095
C     *WFE(I)            * * *            * * *  - PHI DIRECTION            00000096
C     *XSI(I)       VERTICAL MERIDIONAL STATION DISTANCES  (L)              00000097
C     *EM1(4,4)     DIAGONAL BOUNDARY FORCE MATRIX  *OMEGA*  BCIT = 6.      00000100
C     *EM3(4,4)     DIAGONAL BOUNDARY DISPLACEMENT MATRIX *LAMBDA*          00000101
C     *EM5(4)       COLUMN BOUNDARY MATRIX *L*  TOP OF OPEN SHELLS          00000102
C     *EM1N,EM3N,EM5N     AS ABOVE FOR BCIB = 6.                            00000105
C    **E2,POI2,T2,DNA2    PARAMETERS FOR 2ND STRESS                         00000106
C                                                                           00000107
C      *            SET UP IN GEOM, DATLDS, OR DATLYR                       00000275
C      **           MAY BE SET UP IN DATLNK WHEN CONSTANT, BUT USUALLY IN   00000276
C                   DATLDS OR DATLYR                                        00000277
C                                                                           00000279
      DIMENSION   D(150), EK(150), ENT(150), EMT(150), PFE(150),            00000280
     1  PTH(150), PN(150), E1(150), T(150), ALF(150), DNA(150),             00000281
     2  T2(150), E2(150), DNA2(150)                                         00000282
C                                                                           00000299
      EQUIVALENCE      (SDA(1),  EX  ),(SDA(2), GEOMI ),(SDA(3), SPRL ),00000300
     1(SDA(4),  UK    ),(SDA(5),   VK  ),(SDA(6),   WK   ),(SDA(7),  EMK ),00000301
     2(SDA(8),  PSI   ),(SDA(9),   ECX ),(SDA(10), BCIT ),(SDA(11), BCIB),00000302
     3(SDA(12), PFLAG),(SDA(13), STRI),(SDA(14),    FN ),(SDA(15), DEL ),00000303
C              SDA(16,17,18 AND 19) ARE USED FOR STORAGE                    00000304
     4(SDA(20), TLOC ),                                 (SDA(25), POI ),00000305
     1(SDA(26),  D   ),(SDA(176), EK ),(SDA(326), ENT ),(SDA(476), EMT),00000311
     2(SDA(626), PFE ),(SDA(776), PTH),(SDA(926), PN  ),(SDA(1076), E1),00000312
     3(SDA(1226), T  ),(SDA(1376),ALF),(SDA(1526), DNA),(SDA(2498),XSI),00000313
     4(SDA(1676),RHOX),(SDA(1826),GAMA),(SDA(1976), R),(SDA(2126),WTHD),00000314
     5(SDA(2276),WFE ),(SDA(2426),EM1),(SDA(2442), EM3),(SDA(2458),EM5),00000315
     6(SDA(2462),EM1N),(SDA(2478),EM3N),(SDA(2494),EM5N),(SDA(2649),E2),00000316
     7(SDA(2648),POI2),(SDA(2799), T2),(SDA(2949),DNA2)                     00000317
C                                                                           00000339
      EQUIVALENCE      (DA(1),  EKK  ),(DA(2),   AO   ),(DA(3),  HO   ),00000340
     1(DA(4),    E0   ),(DA(5),  SIGO ),(DA(6),  PIXI  ),(DA(7), PTHI  ),00000341
     2(DA(8),   SUM   ),(DA(9),  ENFO ),(DA(10), ENFI  ),(DA(21), FNFOR),00000342
     3(DA(25), THETA )                                                      00000343
C                                                                           00000349
      COMMON     DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,        00000350
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                                   00000351
```

Regional Data Read Subroutine (Cont)

```
      COMMON    SDA(3098), PM(126), ENOT, TSTA(20), TBOT(20), TTOP(20)  00000360
C                                                                       00000368
C                                                                       00000379
    1 DO  400    NS = 1,KKE                                             00000380
C                                                                       00000388
C                                        TEST INDICATOR FOR FIRST PASS  00000389
      IF( SL2 ) 10,200,10                                               00000390
C                                      TEST FOR NEW LOADS CASE ONLY     00000391
   10 IF(PTHI .NE. 0.)  GO TO 200                                       00000392
C                                                   ZERO LOADS AREAS    00000396
      SDA(17)  =  0.                                                    00000397
      SDA(18)  =  0.                                                    00000398
      SDA(19)  =  0.                                                    00000399
      DO   15     I = 1,150                                             00000400
      T(I)      =  0.                                                   00000401
      ENT(I)    =  0.                                                   00000402
      EMT(I)    =  0.                                                   00000403
      PN(I)     =  0.                                                   00000404
      PFE(I)    =  0.                                                   00000405
   15 PTH(I)    =  0.                                                   00000406
C                                                                       00000408
C                                   SET UP R, RHOX, GAMA, WTH, WFE, XSI 00000409
      CALL  GEOM( NS )                                                  00000410
      ENOT   =  1.                                                      00000411
C                                               READ  REGION DATA       00000415
   18 CALL  DECRD (SDA)                                                 00000416
      N  =  EN                                                          00000417
      IF( EX ) 20,60,40                                                 00000418
C                                        CHECKOUT  CONSTANT  DATA       00000419
   20 S3   =   1. /(EO * HO)                                            00000420
      S4   =   1. / SQ6                                                 00000421
      S5   =   AO * S4                                                  00000422
      D     =   D * S3                                                  00000423
      EK    =   EK * S3 /HO **2                                         00000424
      ENT   =   ENT * S4                                                00000425
      EMT   =   EMT * S5 /HO **2                                        00000426
      PFF   =   PFE * S5                                                00000427
      PTH   =   PTH * S5                                                00000428
      PN    =   PN * S5                                                 00000429
      DO    30     I = 2,N                                              00000430
      D(I)   =   D                                                      00000431
      E1(I)   =   E1                                                    00000432
      EK(I)   =   EK                                                    00000433
```

Regional Data Read Subroutine (Cont)

```
      T(I)   =  T                                                     00000434
      ENT(I) =  ENT                                                   00000435
      EMT(I) =  EMT                                                   00000436
      PFE(I) =  PFE                                                   00000437
      ALF(I) =  ALF                                                   00000438
      PTH(I) =  PTH                                                   00000439
      DNA(I) =  DNA                                                   00000440
   30 PN(I)  =  PN                                                    00000441
   31 S1  =  1. - POI                                                 00000445
      S2  =  1. + POI                                                 00000446
      GO  TO  305                                                     00000450
C                                                                     00000454
   40 S1  =  1. - POI                                                 00000455
      S2  =  1. + POI                                                 00000456
      ENOT  =  0.                                                     00000457
      IF(EX .EQ. 2.)  GO TO 50                                        00000458
C                      CONSTANT SECTION PROPERTIES, TEMP. LOADS       00000459
      IF(D .EQ. 1.E+10)  GO TO 42                                     00000460
      S3  =  E1 /(1. - POI **2)                                       00000461
      S4  =  2. * ABS(DNA) /HO                                        00000462
      D  =  S3 /EO * S4                                               00000463
      EK  =  S4 **2 * D /12.                                          00000464
      GO TO 43                                                        00000465
   42 D  =  D(2) /EO /HO                                              00000466
      EK  =  EK(2) /EO /HO **3                                        00000467
   43 ENT  =  E1 * ALF /S1 * T/SIGO * 2. /HO * DNA                    00000468
      EMT  =  0.                                                      00000469
      DO   45     I = 2,N                                             00000470
      ENT(I)  =  ENT                                                  00000471
      EMT(I)  =  EMT                                                  00000472
      ALF(I)  =  ALF                                                  00000473
      T(I)    =  T                                                    00000474
      D(I)    =  D                                                    00000475
      EK(I)   =  EK                                                   00000476
      E1(I)   =  E1                                                   00000477
   45 DNA(I)  =  DNA                                                  00000478
      GO  TO  305                                                     00000480
C                      CONSTANT PRESSURES, NO TEMPERATURES            00000481
   50 S5  =  AO /SQ6                                                  00000485
      PN  =  PN * S5                                                  00000486
      PFE  =  PFE * S5                                                00000487
      PTH  =  PTH * S5                                                00000488
      DO   55     I = 2,N                                             00000492
```

Regional Data Read Subroutine (Cont)

```
      PN(I)    =  PN                                                    00000493
      PFE(I)   =  PFE                                                   00000494
   55 PTH(I)   =  PTH                                                   00000495
      GO  TO   70                                                       00000497
C                                                                       00000498
C                                           SET UP PN, PFE, PTH, TMP    00000499
   60 CALL  DATLDS( NS )                                                00000500
C                                                                       00000501
      IF(PTHI .GT. 0.)  GO TO 120                                       00000510
   70 IF(PFLAG .LT. 0.) GO TO 71                                        00000520
      IF(SL2 .EQ. 0.)  GO TO 74                                         00000521
   71 WRITE (6,72)  NS                                                  00000522
   72 FORMAT( 1H1, 27X, 40HSECTION AND MATERIAL PROPERTIES - REGION, I4)00000524
   74 IF(ABS(FX) .EQ. 1.)  GO TO 100                                    00000525
C                                                                       00000526
C                               SET UP D, EK, ENT, FMT, E1, T, ALF, DNA 00000529
   75 CALL  DATLYR( NS )                                                00000530
C                                                                       00000534
  100 SDA(16)   =  ENOT                                                 00000535
C                                         SAVE DATA ON TAPE 12 OR 13    00000539
      WRITE  (KTPW)    (SDA(I), I = 1,3098)                             00000540
      IF(PFLAG .LT. 0.) GO TO 101                                       00000541
      IF(SL2 .EQ. 0.)  GO TO 103                                        00000542
C                                                                       00000546
C                                     ALWAYS PRINT ON NEGATIVE PFLAG    00000547
C                                     OR FOR FIRST FOURIER COMPONENT    00000548
C                                                                       00000549
  101 WRITE (6,102)  EX, POI, POI2, STRI, (I, D(I), EK(I),F1(I), ALF(I),00000550
     1 DNA(I), T(I), I = 1,N)                                           00000551
  102 FORMAT   (///,15X, 4HEX =, 1PE13.4, 8X, 5HPOI =, E13.4, 8X,       00000560
     1 6HPOI2 =, E13.4 //30X,35HLAYER NO. FOR SECOND STRESS PRINT = ,   00000561
     2 E13.4 //                                      / 3X,1HI, 8X,      00000562
     34HD(I),13X,5HEK(I),12X,4HE(I), 12X, 6HALF(I), 11X, 6HDNA(I), 12X, 00000563
     4 4HT(I) // (I4, 1P6E17.7) )                                       00000564
C                                                                       00000569
  103 WRITE (6,104)  NS, ENF, SDA(18), SDA(19), SDA(17), (I, PFF(I),    00000570
     1 PTH(I), PN(I), ENT(I), EMT(I), I = 1,N)                          00000571
  104 FORMAT  (1H1,32X,14HLOADS   REGION,I4,10X, 5HENF =,1PE13.4 // 43X,00000580
     1 24HDISCONTINUITY CONDITIONS //15X,10HP(FORCE) =, E13.4,  8X,     00000581
     2 11HM(MOMENT) =, E13.4, 8X, 13HANGLE(PSI0) =, E13.4 // 41X,       00000582
     3 28HMECHANICAL AND THERMAL LOADS // 3X, 1HI,13X, 6HP(PHI),13X,    00000583
     4 8HP(THETA),14X, 4HP(N),15X, 6HENT(I),14X, 6HEMT(I) //            00000584
     5 (I5,1P5E20.4 ))                                                  00000585
```

Regional Data Read Subroutine (Cont)

```
C                                                                      00000599
      GO  TO  400                                                      00000600
C                                                                      00000608
  120 IF(ENOT .EQ. 0.)  GO TO 100                                      00000610
      GO  TO  70                                                       00000612
C                                                   OTHER PASSES       00000699
  200 READ    (KTPR)    (SDA(I), I = 1,3098)                           00000700
      N  =  EN                                                         00000701
      ENOT  =  SDA(16)                                                 00000702
      EX  =  0.                                                        00000703
      IF( PTHI ) 18,210,60                                             00000704
  210 PTHI  =  1.                                                      00000706
      GO  TO  60                                                       00000710
C                                              SECOND STRESS PARAMETERS00000739
  305 STRI  =  1.                                                      00000740
      POI2  =  POI                                                     00000742
      S3  = (1. - POI **2) * EO * HO                                   00000744
      DO   308   I = 1,N                                               00000746
      E2(I)  =  E1                                                     00000748
      T2(I)  =  T * ALF                                                00000750
  308 DNA2(I)  =  D /E1 * S3 + DNA                                     00000752
C                                                                      00000753
      IF(EX .GT. 0.) GO TO 60                                          00000754
      WRITE (6,315) NS                                                 00000755
  315 FORMAT( 1H1, 27X, 40HSECTION AND MATERIAL PROPERTIES - REGION, I4)00000756
      GO  TO  100                                                      00000758
C                                                                      00000759
  400 CONTINUE                                                         00000760
      IF(ENF .NE. ENFO)  GO TO 410                                     00000762
      SL2  = -1.                                                       00000764
  410 RETURN                                                           00000999
      END                                                              00001000
```

Regional Data Read Subroutine (Cont)

```
$IBFTC GMTRY                                                              00000010
C     GFOMETRY COMPUTATION SUBROUTINF                 6J-148  ** LINK 2   00000020
C                                                                         00000030
      SUBROUTINF  GFOM( IRGN )                                            00000040
C                                                                         00000050
C  NOMFNCLATURF                                                           00000060
C        GMI    -  GEOMETRY INDICATOR                                     00000070
C               =  1.0  - CONE - CYLINDER                      **         00000080
C               =  2.0  - SPHERE - TOROID                      **         00000090
C               =  3.0  - GFNERAL DISCRFTE POINTS              **         00000100
C               =  4.0  - ELLIPSE                              **         00000105
C               =  5.0  - HYPERBOLA                            **         00000110
C               =  6.0  - PARABOLA                             **         00000115
C                                                                         00000120
C     EN          NO. OF POINTS /REGION                                   00000130
C     PFLAG       PRINT INDICATOR, NON-ZERO PRINTS ALL INPUT DATA         00000140
C     BCITP       BOUNDARY CONDITION INDICATOR, TOP                       00000150
C     BCIBM           ** DITTO **  BOTTOM                                 00000160
C                 1. = FRFE,    2. = ROLLER,   3. = CLAMPED (FIXED),      00000170
C                 4. = SIMPLY SUPPORTED (HINGED),    5. = COMPLETE,       00000180
C                 6. = SPECIAL, READ IN MATRICES   9. = CLOSED            00000190
C                 ** MUST USF 6 WHEN LOAD FNTERFD IN EM5X OR EMN5         00000200
C     PSI         DISCONTINUITY ANGLE AT THE END OF THE REGION  (DEGREES)00000210
C     ECX         ECCENTRICITY OF REFERENCE SUR.ACE AT BOTTOM DISCONT.    00000220
C     SPRL        LOCATION OF SPRING                                      00000230
C     UK          SPRING VALUE - PHI DIRECTION                            00000240
C     VK             * * *     - THETA DIRECTION                          00000250
C     WK             * * *     - N DIRECTION                              00000260
C     EMK            * * *     - MOMENT                                   00000270
C               **                                             **         00000280
C                    GMI  =  1.0                                          00000290
C                 RA1    =   RADIUS AT STATION 1                          00000300
C                 AXL    =   AXIAL SURFACE LENGTH                         00000310
C                 ANX    =   ANGLF - GFNERATOR AND AXIS OF REVOLUTION     00000320
C               **                                             **         00000330
C                    GMI  =  2.0                                          00000340
C                 RC     =   RADIUS OF CURVATURE                          00000350
C                 ROFF   =   OFFSET DISTANCE TO CENTER OF CURVATURE       00000360
C                 PHIO   =   INITIAL OPENING ANGLE FROM VERTICAL AXIS     00000370
C                 PHIN   =   FINAL OPENING ANGLE FROM VERTICAL AXIS       00000380
C               **                                             **         00000390
C                    GMI  =  3.0  (-3.0 DISCRFTE ARCLFNGTHS)              00000400
C                 FM     =   NO. OF RIPT'S GIVFN                          00000410
```

Geometry Computation Subroutine

```
C              RIPT  =   DISCRETE RADII                                   00000420
C              XIPT = DISCRETE XI'S  (OR ARCLENGTHS)                      00000421
C              RCURV = RADIUS OF CURVATURE IN THE MERIDIONAL DIRECTION00000422
C              RCURZ = RAD. OF CURV. IN THE CIRCUMFERENTIAL DIRECTION 00000423
C             **                                         **               00000431
C                  GMI = 4.0                                              00000432
C              RFF    =   OFFSET DISTANCE TO AXIS OF REVOLUTION           00000433
C              SPNO   =   INITIAL OPENING ANGLE FROM VERTICAL AXIS        00000434
C              SPNN   =   FINAL OPENING ANGLE FROM VERTICAL AXIS          00000435
C              A      =   SEMI-AXIS PARALLEL TO THE AXIS OF REVOLUTION 00000436
C              B      =   SEMI-AXIS PERPENDICULAR TO THE AXIS OF REV.  00000437
C             **                                         **               00000438
C                  GMI = 5.0  (SAME AS GMI = 4.0)                         00000440
C             **                                         **               00000441
C                  GMI = 6.0  (SAME AS GMI = 4.0, BUT NO B)               00000445
C             **                                         **               00000446
C      EM1X(4,4)  DIAGONAL BOUNDARY FORCE MATRIX  (OMEGA)  BCIT = 6.      00000450
C      EM3X(4,4)  DIAGONAL BOUNDARY DISPLACEMENT MATRIX (LAMBDA)          00000460
C      EM5X(80)   COL. BND. MATRICES (L), TOP OF OPEN SHELL, ALL ENF      00000470
C      EMN1.EMN2.EMN3      AS ABOVE FOR BCIB = 6.                         00000480
C                                                                         00000490
       DIMENSION   BETA(150), BETADP(150), BETAP(150), DLR(754),          00000500
     1 FM1(4,4), FM1N(4,4), EM1X(4), EM3(4,4), FM3N(4,4), EM3X(4),        00000501
     2 FM5(4), FM5N(4), FM5X(80), FMN1(4), FMN3(4), EMN5(80),             00000502
     3 GAMA(150), GDA(800), R(150), RCRV(150), RCRZ(150), RCURV(150),     00000503
     4 RCURZ(150), RHOX(150), RIPT(150), RJ(755), RR(150), RRJ(12),       00000504
     5 SARB(150), STAP(4), STAW(16), SURF(150), SURN(750), WF(150),       00000505
     6 WFE(150), WFP(4), WFW(16), WT(150), WTH(150), XIPT(150), XJ(755),00000506
     7 XSI(150), ZETA(750), ZTA(150)                                      00000507
C                                                                         00000640
       EQUIVALENCE      (GDA(1),   GMI),(GDA(2),     EN),(GDA(3), PFLAG),00000650
     1(GDA(4),  BCITP),(GDA(5), BCIBM),(GDA(6),   GPSI),(GDA(7),  GECX),00000660
     2(GDA(8),  GSPRL),(GDA(9),   GUK),(GDA(10),   GVK),(GDA(11),  GWK),00000670
     3(GDA(12),  GEMK),                             (GDA(15), RA1, RC),00000680
     4(GDA(16), AXL, ROFF),(GDA(17), ANX, PHI0),      (GDA(18), PHIN),00000690
     5(GDA(19),     FM),(GDA(20), RIPT),(GDA(170), XIPT),                 00000700
     6(GDA(320),RCURV),(GDA(470),RCURZ),(GDA(620),EM1X),                  00000710
     7(GDA(624),EM3X),(GDA(628),EM5X),(GDA(708),EMN1),(GDA(712),EMN3),   00000720
     8(GDA(716),EMN5),(GDA(796),RFF),(GDA(797),SPN0),(GDA(798),SPNN),    00000730
     9(GDA(799), A), (GDA(800), B)                                        00000740
C                                                                         00000750
       EQUIVALENCE      (DA(1),  EKK  ),(DA(2),   A0   ),(DA(3),  H0   ),00000760
     1(DA(4),    E0   ),(DA(5),  SIG  ),(DA(6),  PIXI  ),(DA(7), PTHI  ),00000770
```

Geometry Computation Subroutine (Cont)

```
     2(DA(8),   SUM    ),(DA(9),   ENF0 ),(DA(10), ENFI   ),(DA(21), ENFOR),00000780
     3(DA(25), THETA )                                                     00000790
C                                                                          00000800
      EQUIVALENCE(SDA(    1),    EX),(SDA(    2),GFOMI),(SDA(    3), SPRL), 00000810
     1           (SDA(    4),    UK),(SDA(    5),    VK),(SDA(    6),    WK), 00000820
     2           (SDA(    7),   EMK),(SDA(    8),   PSI),(SDA(    9),   ECX), 00000830
     3           (SDA(   10),  BCIT),(SDA(   11),  BCIB),(SDA(   12),  PFLG), 00000840
     4           (SDA(   13),  STRI),(SDA(   14),   ENS),(SDA(   15),   DEL), 00000850
     5           (SDA(   20),  TLOC),                    (SDA(   25),   POI),00000860
     1           (SDA(   26),     D),(SDA(  176),    FK),(SDA(  326),   FNT), 00000870
     2           (SDA(  476),   EMT),(SDA(  626),   PFE),(SDA(  776),   PTH), 00000880
     3           (SDA(  926),    PN),(SDA( 1076),    E1),(SDA( 1226),     T), 00000890
     4           (SDA( 1376),   ALF),(SDA( 1526),   DNA),(SDA( 2426),   EM1), 00000900
     5           (SDA( 2442),   EM3),(SDA( 2458),   EM5),(SDA( 2498),   XSI), 00000910
     6           (SDA( 1676),  RHOX),(SDA( 1826),  GAMA),(SDA( 1976),     R), 00000920
     7           (SDA( 2126),   WTH),(SDA( 2276),   WFE),(SDA( 2462),  EM1N), 00000930
     8           (SDA( 2478),  EM3N),(SDA( 2494),  EM5N)                       00000940
C                                                                          00000950
      COMMON     DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,       00000960
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                                  00000970
      COMMON     SDA(3098)                                                 00000980
C                                                                          00000990
      DO 1   I = 1,800                                                     00001000
    1 GDA(I)   =   0.                                                      00001010
C                                                                          00001020
    2 CALL DECRD(GDA)                                                      00001030
      N = EN                                                               00001040
      NN = N - 1                                                           00001050
      CALL OPEXQ (13)                                                      00001060
C                                               MOVE DATA TO SDA REGION    00001070
      ENS   =   EN                                                         00001080
      GEOMI   =   GMI                                                      00001090
      PFLG   =   PFLAG                                                     00001100
      PSI   =   GPSI                                                       00001110
      ECX   =   GECX                                                       00001120
      SPRL   =   GSPRL                                                     00001130
      UK   =   GUK                                                         00001140
      VK   =   GVK                                                         00001150
      WK   =   GWK                                                         00001160
      EMK  =   GEMK                                                        00001170
      BCIT   =   BCITP                                                     00001180
      BCIB   =   BCIBM                                                     00001190
      IF(BCIT .NE. 6.)   GO TO 17                                          00001200
```

Geometry Computation Subroutine (Cont)

```
      DO  16      I = 1,4                                                   00001210
      EM1(I,I)   =  EM1X(I)                                                 00001230
      EM3(I,I)   =  EM3X(I)                                                 00001240
   16 EM5(I)   =  EM5X(I)                                                   00001250
   17 IF(BCIB .NE. 6.) GO TO 19                                             00001260
      DO   18     I = 1,4                                                   00001270
      EM1N(I,I)   =  EMN1(I)                                                00001280
      EM3N(I,I)   =  EMN3(I)                                                00001290
   18 EM5N(I)   =  EMN5(I)                                                  00001300
   19 IF(BCIT .EQ. 0.) BCIT = 1.E+10                                        00001310
      IF(BCIB .EQ. 0.) BCIB = 1.E+10                                        00001320
C                                                                           00001330
      IF (ABS(GMI) - 2.0) 20, 35, 50                                        00001340
C                                                                           00001350
C                    CONE - CYLINDER                              **        00001360
C                                                                           00001370
   20 DEL =  AXL/(EN - 1.0)                                                 00001380
      SINFI  = SIND(ANX)                                                    00001390
      COSFI  = COSD(ANX)                                                    00001400
      IF(ABS(ANX) .NE. 90.0) GO TO 21                                       00001401
      SNFI  =  1.0                                                          00001402
      SINFI  =  SIGN(SNFI,SINFI)                                            00001403
      COSFI  =  0.0                                                         00001404
   21 XSI(1) = 0.0                                                          00001410
      WTH(1) = A0 * COSFI/RA1                                               00001420
      WFE(1) = 0.0                                                          00001430
      RHOX(1) = RA1/A0                                                      00001440
      R(1) = RA1                                                            00001450
C                                                                           00001460
      DO 30 I = 2,N                                                         00001470
      R(I)  = R(I-1) + DEL * SINFI                                          00001480
      XSI(I) = XSI(I-1) + DEL * COSFI                                       00001490
      WTH(I) = A0 * COSFI /R(I)                                             00001500
      WFE(I) = 0.0                                                          00001510
   30 RHOX(I) = R(I)/A0                                                     00001520
C                                                                           00001530
      WRITE (6, 32) IRGN, EN, DEL, BCIT, BCIB, PSI, ECX, SPRL, UK, VK,      00001540
     1 WK, EMK, PFLAG, GEOMI, RA1, AXL, ANX                                 00001550
   32 FORMAT  (1H1, 33X,24HGEOMETRY DATA FOR REGION ,I4,18H   (CONE-CYLI00001560
     1NDER) /// 7X,15HNO. OF STATIONS,13X,7HN     = ,1PE13.4//7X,23HFINIT00001570
     2E DIFFERENCE INCR.,5X,7HDEL   = ,E13.4//7X,19HBOUNDARY CONDITIONS, 00001580
     3 9X,7HBCIT = ,E13.4/ 35X,7HBCIB = ,E13.4//7X,24HDISCONTINUITY COND00001590
     4ITIONS,4X,7HPSI  = ,E13.4/35X,7HECX  = ,E13.4// 7X,16HSPRING CONDI00001600
```

Geometry Computation Subroutine (Cont)

```
     5TION,12X,7HSPRL = ,E13.4 / 7X,7HUK   = ,E13.4,4X, 7HVK   = ,E13.4,
     6 4X, 7HWK   = ,E13.4, 4X, 7HMK   = ,E13.4 // 7X,10HOTHER DATA /
     7 7X, 7HPFLAG= ,E13.4, 4X, 7HGEOMI= ,E13.4,
     8             / 7X,7HRA1   = ,E13.4, 4X, 7HAXL   = ,E13.4, 4X,
     9 7HANX   = ,E13.4 )
      GO TO 295
C
C                 SPHERE - TOROID                              **
C
   35 ANGSP = PHIN - PHIO
      DEL =  ANGSP/(EN - 1.0)
      AM = 1.0
      AMU = SIGN(AM,DFL)
      XSI(1) =  0.0
      BPHI = PHIO
      BSINP = SIND(PHIO)
      BCOSP = COSD(PHIO)
      R(1) = RC * BSINP + ROFF
C
      DO 40 I = 1,NN
      APHI = BPHI + DEL
      ASINP = SIND(APHI)
      ACOSP = COSD(APHI)
      R(I+1) = R(I) + RC * (ASINP - BSINP)
      XSI(I+1) = XSI(I) + RC * (BCOSP - ACOSP)
      WFE(I) = AO/ RC * AMU
      IF(ROFF .EQ. 0.0) GO TO 38
      WTH(I) = AO * BSINP / R(I) * AMU
      GO TO 39
   38 WTH(I)  =  WFE(I)
   39 RHOX(I) = R(I)/AO
      BPHI = APHI
      BSINP = ASINP
      BCOSP = ACOSP
   40 CONTINUE
      DEL = ABS(DEL)
      WFE(N) = AO/RC * AMU
      IF(ROFF .EQ. 0.0) GO TO 45
      WTH(N) = AO * BSINP / R(N) * AMU
      GO TO 46
   45 WTH(N)  =  WFE(N)
   46 RHOX(N) = R(N)/AO
      DEL = DEL * RC * 0.01745329
```

Geometry Computation Subroutine (Cont)

```
C                                                                       00002040
      WRITE (6, 49) IRGN, FN, DEL, BCIT, BCIB, PSI, ECX, SPRL, UK, VK,  00002050
     1 WK, HMK, PFLAG, GEOMI, RC, ROFF, PHI0, PHIN                      00002060
   49 FORMAT  (1H1, 33X,24HGEOMETRY DATA FOR REGION ,I4,18H   (SPHERE-I00002070
     1ROID) /// 7X,15HNO. OF STATIONS,13X,7HN     = ,1PE13.4//7X,23HFINIT00002080
     2E DIFFERENCE INCR.,5X,7HDEL   = ,E13.4//7X,19HBOUNDARY CONDITIONS, 00002090
     3 9X,7HBCIT = ,E13.4/ 35X,7HBCIB = ,E13.4//7X,24HDISCONTINUITY COND00002100
     4ITIONS,4X,7HPSI   = ,E13.4/35X,7HECX   = ,E13.4// 7X,16HSPRING CONDI00002110
     5TION,12X,7HSPRL = ,E13.4 / 7X,7HUK    = ,E13.4,4X, 7HVK    = ,E13.4,00002120
     6 4X, 7HWK    = ,E13.4, 4X, 7HMK    = ,E13.4 // 7X,10HOTHER DATA /   00002130
     7 7X, 7HPFLAG= ,E13.4, 7X, 7HGFOMI= ,E13.4,                        00002140
     8  / 7X, 7HRC    =, E13.4, 7X, 7HROFF  =, E13.4, 7X, 7HPHI0  =,      00002150
     9 E13.4, 7X, 7HPHIN  =, E13.4 )                                    00002160
      GO TO 295                                                         00002170
C                                                                       00002180
   50 IF (ABS(GMI) - 4.0) 200,51,150                                    00002190
C                                                                       00002200
C                            ELLIPSE                                    00002210
C                                                                       00002220
   51 WRITE (6,52) RFF, SPNO, SPNN, A, B                                00002230
   52 FORMAT(1H-,39X,32HCONIC REPRESENTATION  -  ELLIPSE //7X,7HRFF  = ,00002240
     1E13.4, 4X,7HSPNO = ,E13.4, 4X, 7HSPNN = ,E13.4, 4X,7HA     = ,E13.400002250
     2 / 7X,7HB     = ,E13.4 )                                          00002260
      ANGSP = SPNN - SPNO                                               00002270
      DEL = ANGSP /749.0                                                00002280
      AM = 1.0                                                          00002290
      AMU = SIGN(AM,DEL)                                                00002300
      BMU = AMU                                                         00002310
      DO 54 JR = 1,750                                                  00002320
      BJR = JR - 1                                                      00002330
      ZETA(JR) = SPNO + BJR * DEL                                       00002340
      ASINP = SIND(ZETA(JR))                                            00002350
      A2SIN = ASINP * ASINP                                             00002360
      AA2 = A * A                                                       00002370
      BB2 = B * B                                                       00002380
      BETA = A * B/SQRT(BB2 + (AA2-BB2) * A2SIN)                        00002390
      XJ(JR) = BETA * COSD(ZETA(JR))                                    00002400
      RJ(JR) = BETA * ASINP + RFF                                       00002410
   54 CONTINUE                                                          00002420
   58 SURN(1) = 0.0                                                     00002430
      DO 60 JR = 1,749                                                  00002440
      DLR = RJ(JR+1) - RJ(JR)                                           00002450
      DDL = XJ(JR+1) - XJ(JR)                                           00002460
```

Geometry Computation Subroutine (Cont)

```
      DLS = SQRT(DLR* DLR + DDL * DDL)                                  00002470
   60 SURN(JR+1) = SURN(JR) + DLS                                       00002480
      DEL = SURN(750)/(EN - 1.0)                                        00002490
      SURF(1) = 0.0                                                     00002500
      DO 65 I = 1,NN                                                    00002510
   65 SURF(I+1) = SURF(I) + DEL                                         00002520
      CALL CODIMA(N, SURF, R, SURN, RJ, 750, 1.0)                       00002530
      CALL CODIMA(N, SURF, XSI, SURN, XJ, 750, 1.0)                     00002540
      CALL CODIMA(N, SURF, ZTA, SURN, ZETA, 750, 1.0)                   00002550
      DO 100 I = 1,N                                                    00002560
      ASINP = SIND(ZTA(I))                                              00002570
      ACOSP = COSD(ZTA(I))                                              00002580
      A2SIN = ASINP * ASINP                                             00002590
      A2COS = ACOSP * ACOSP                                             00002600
      AA2 = A * A                                                       00002610
      IF (ABS(GMI) .GT. 5.0) GO TO  75                                  00002620
      BB2 = B * B                                                       00002630
      AMB2 = AA2 - BB2                                                  00002640
      APB2 = AA2 + BB2                                                  00002650
      IF (ABS(GMI) .EQ. 5.0) GO TO  70                                  00002660
      BETA    = A * B/SQRT(BB2 + AMB2 * A2SIN)                          00002670
      BETAP    = (-A*B*AMB2*ASINP*ACOSP)/ SQRT((BB2+AMB2*A2SIN)**3)     00002680
      BETADP    = (A*B*AMB2)/SQRT((BB2+AMB2*A2SIN)**5)  * (AA2*A2SIN +  00002690
     1 A2COS * (A2SIN*AMB2 - BB2) )                                     00002700
      GO TO  85                                                         00002710
   70 B2MSMS = BB2 - APB2 * A2SIN                                       00002720
      BM = 1.0                                                          00002730
      BMU = SIGN(RM,B2MSMS)                                             00002740
      BMU = AMU * BMU                                                   00002750
      B2MSMS = ABS(B2MSMS)                                              00002760
      BETA    = A* B  / SQRT( B2MSMS )                                  00002770
      BETAP    = ( A*B* APB2 * ASINP * ACOSP) / SQRT(B2MSMS**3)         00002780
      BETADP    = A*B* APB2 *(( A2COS -A2SIN) * B2MSMS + 3.0 * APB2*    00002790
     1A2SIN * A2COS ) / SQRT( B2MSMS **5)                               00002800
      GO TO  85                                                         00002810
   75 IF (GMI .LT. 0.0) GO TO  80                                       00002820
      BETA    = (2. * A * ACOSP) /A2SIN                                 00002830
      BETAP    = -(A2COS + 1.0) * 2. * A/(A2SIN * ASINP)                00002840
      BETADP    = 2.*A* ACOSP * (A2COS + 5.) / (A2SIN * A2SIN)          00002850
      GO TO  85                                                         00002860
   80 BETA   =2.0 *A *ASINP/A2COS                                       00002870
      BETAP    = 2.0* A*(A2SIN + 1.0)/(A2COS* ACOSP                   ) 00002880
      BETADP    = 2.0 * A * ASINP * (A2SIN + 5.0) /(A2COS * A2COS)      00002890
```

Geometry Computation Subroutine (Cont)

```
 85 BTA2 = BETA     * BETA                                              00002900
    BTAP2 = BETAP     * BFTAP                                           00002910
    IF(R(I) .EQ. 0.0) GO TO  90                                         00002920
    WFE(I) = (BTA2 + 2.*BTAP2 - BETA     * BETADP    ) /SQRT((BTA2 +    00002930
   1 BTAP2) **3) * BMU                                                  00002940
    WTH(I) =(-BETAP    *AC' ,P + BETA     * ASINP) /(SQRT(BTA2+BTAP2) * 00002950
   1 (BETA *ASINP + RFT  ., * AMU                                       00002960
    GO TO 100                                                           00002970
 90 IF (I .EQ. 1) GO TO 100                                             00002980
    WFE(N) = WFE(NN)                                                    00002990
    WTH(N) = WTH(NN)                                                    00003000
100 CONTINUE                                                            00003010
    IF(R(1) .NE.  0.0) GO TO 105                                        00003020
    WFE(1) = WFE(2)                                                     00003030
    WTH(1) = WTH(2)                                                     00003040
105 RHOX (1) = R(1) /A0                                                 00003050
    DELSQ = DEL * DEL                                                   00003060
    DO 110    I = 1,NN                                                  00003070
110 RHOX(I+1) = R(I+1) /A0                                              00003080
    WRITE (6,120)IRGN, EN, DEL, BCIT, BCIB, PSI, ECX, SPRL, UK, VK,     00003090
   1 WK, EMK, PFLAG, GEOMI                                              00003100
120 FORMAT (1H1,31X, 24HGEOMETRY DATA FOR REGION ,I4,12H    (CONICS), 00003120
   1         ///7X,15HNO. OF STATIONS,13X,7HN     = ,1PE13.4//7X,23HFINIT00003130
   2E DIFFERENCE INCR.,5X,7HDEL  = ,E13.4//7X,19HBOUNDARY CONDITIONS, 00003140
   3 9X,7HBCIT = ,E13.4/ 35X,7HBCIB = ,E13.4//7X,24HDISCONTINUITY COND00003150
   4ITIONS,4X,7HPSI  = ,E13.4/35X,7HECX  = ,E13.4// 7X,16HSPRING CONDI00003160
   5TION,12X,7HSPRL = ,E13.4 / 7X,7HUK   = ,E13.4,4X, 7HVK   = ,E13.4,00003170
   6 4X, 7HWK   = ,E13.4, 4X, 7HMK   = ,E13.4 // 7X,10HOTHER DATA /   00003180
   7 7X, 7HPFLAG= ,E13.4, 4X, 7HGEOMI= ,E13.4 )                         00003190
    GO TO 295                                                           00003200
C                                                                       00003210
150 IF (ABS(GMI) .GT. 5.0) GO TO 180                                    00003220
C                                                                       00003230
C                             HYPERBOLA                                 00003240
C                                                                       00003250
160 WRITE (6,164)RFF, SPNO, SPNN, A, B                                  00003260
164 FORMAT(1H-,38X,32HCONIC REPRESENTATION - HYPERBOLA //7X,7HRFF  = ,00003270
   1E13.4, 4X,7HSPNO = ,E13.4, 4X, 7HSPNN = ,E13.4, 4X,7HA    = ,E13.400003280
   2 / 7X,7HB    = ,E13.4 )                                             00003290
    ANGSP = SPNN - SPNO                                                 00003300
    DEL = ANGSP /749.0                                                  00003310
    AM = 1.0                                                            00003320
    AMU = SIGN(AM,DEL)                                                  00003330
```

Geometry Computation Subroutine (Cont)

```
      BMU = AMU
      DO 170   JR = 1,750
      BJR = JR - 1
      ZETA(JR) = SPNO + BJR * DEL
      ASINP = SIND(ZETA(JR))
      A2SIN = ASINP * ASINP
      BB2 = B * B
      AA2 = A * A
      B2MSMS = BB2 - ( AA2 + BB2 ) * A2SIN
      B2MSMS = ABS( B2MSMS )
      BETA   = A * B / SQRT ( B2MSMS )
      XJ(JR) = BETA * COSD(ZETA(JR))
      RJ(JR) = BETA * ASINP + RFF
  170 CONTINUE
      GO TO 58
C                         PARABOLA
C
  180 WRITE (6,185)RFF, SPNO, SPNN, A
  185 FORMAT(1H-,38X,32HCONIC REPRESENTATION - PARABOLA  //7X,7HRFF  = ,
     1E13.4, 4X,7HSPNO = ,E13.4, 4X, 7HSPNN = ,E13.4, 4X,7HA    = ,E13.4
     2 )
      ANGSP = SPNN - SPNO
      DEL = ANGSP/749.0
      AM = 1.0
      AMU = SIGN(AM,DEL)
      BMU = AMU
      DO  195   JR = 1,750
      BJR = JR - 1
      ZETA(JR) = SPNO + BJR * DEL
      ASINP = SIND(ZETA(JR))
      ASSIN = ASINP * ASINP
      ACOSP = COSD(ZETA (JR))
      ACCOS = ACOSP * ACOSP
      IF (GMI .LT. 0.0) GO TO 190
      BETA = (2. * A * ACOSP)/ASSIN
      GO TO 191
  190 BETA = 2. * A * ASINP/ACCOS
  191 XJ(JR) = BETA * ACOSP
      RJ(JR) = BETA * ASINP + RFF
  195 CONTINUE
      GO TO 58
C
C                    GENERAL DISCRETE POINTS              **
```

Geometry Computation Subroutine (Cont)

```
C
  200 M  =  EM
      MM = M - 1
      MM2 = M- 2
C
      SARB(1) = 0.0
      IF (GMI) 235,205,205
  205 DO   230   IL = 1,MM
      DLT = XIPT(IL+1) - XIPT(IL)
      K = 10
      AK = K
      DDL = DLT/AK
      KP1 = K + 1
      DO   210   JI = 1,KP1
      AJI = JI - 1
      XJ(JI) = XIPT(IL) + AJI * DDL
  210 CONTINUF
C
      CALL CODIMA (KP1,XJ, RRJ, XIPT, RIPT, M, 1.0)
      DO 220 I = 2,K
  220 RJ(I) =  (RRJ(I-1) + RRJ(I) + RRJ(I+1) )/3.0
      RJ(1) = RRJ(1)
      RJ(KP1) = RRJ(KP1)
C
      SURB = 0.0
      DO   225   JR = 1,K
      DLR(JR) = RJ(JR+1) - RJ(JR)
      DLS    =  SQRT(DLR(JR)**2 + DDL**2)
  225 SURB = SURB + DLS
      SARB(IL+1) = SARB(IL) + SURB
  230 CONTINUE
      GO TO 245
  235 DO   240   I = 1,M
  240 SARB(I) = XIPT(I)
  245 DEL = SARB(M) /(EN - 1.0)
C
      SURF(1) = 0.0
      DO  250   I = 1,NN
  250 SURF(I+1) = SURF(I) + DEL
      IF (RCURV .EQ. 0.0) GO TO 260
      CALL CODIMA(N, SURF,RCRV, SARB, RCURV, M, 1.0)
      CALL CODIMA(N,SURF, RCRZ, SARB, RCURZ, M, 1.0)
C
```

Geometry Computation Subroutine (Cont)

```
  260 CALL CODIMA (N,SURF, R, SARB, RIPT, M, 1.0)
C
      CALL CODIMA (N, SURF, XSI, SARB, XIPT, M, -1.0)
  265 MLN = N - 2
      NSM = 1
  270 DO   275   I = 3,MLN
      RR(I) = (-3.*R(I-2) + 12.*R(I-1) + 17.*R(I) + 12.*R(I+1) - 3. *
     1 R(I+2) )/ 35.0
  275 CONTINUE
      RR(NN) = R(NN)
      RR(2) = R(2)
      RR(N) = R(N)
      RR(1) = R(1)
      IF (NSM .EQ. 25) GO TO 285
      NSM = NSM + 1
      DO 280 I = 1,N
  280 R(I) = RR(I)
      GO TO 270
  285 RHOX(1) = RR(1)/AO
      DELSQ = DEL * DEL
      DO    288    I = 1,NN
  288 RHOX(I+1) = RR(I+1) /AO
C
      WRITE (6,290) IRGN, EN, DEL, BCIT, BCIB, PSI, ECX, SPRL, UK, VK,
     1 WK, EMK, PFLAG, GEOMI, (RIPT(I), XIPT(I), I = 1,M)
  290 FORMAT (1H1, 31X, 24HGEOMETRY DATA FOR REGION ,I4,20H   (DISCRETE
     1POINTS)///7X,15HNO. OF STATIONS,13X,7HN    = ,1PE13.4//7X,23HFINIT
     2E DIFFERENCE INCR.,5X,7HDEL   = ,E13.4//7X,19HBOUNDARY CONDITIONS,
     3 9X,7HBCIT = ,E13.4/ 35X,7HBCIB = ,E13.4//7X,24HDISCONTINUITY COND
     4ITIONS,4X,7HPSI   = ,E13.4/35X,7HECX   = ,E13.4// 7X,16HSPRING CONDI
     5TION,12X,7HSPRL  = ,E13.4 / 7X,7HUK    = ,E13.4,4X, 7HVK    = ,E13.4,
     6 4X, 7HWK    = ,E13.4, 4X, 7HMK    = ,E13.4 // 7X,10HOTHER DATA /
     7 7X, 7HPFLAG= ,E13.4, 4X, 7HGEOMI= ,E13.4,
     8///43X, 1HR, 18X, 2HXI //(30X,1P2E20.7) )
       IF (RCURV .NE. 0.0) GO TO 440
C
C                        COMPUTE GAMA                               **
C
  295  DEL = DEL/ AO
       DELSQ = DEL * DEL
       DO 305 I = 1,N
      DENM = 12. * RHOX(I) * DEL
      DENMP= 2. * [illegible]) * DEL
```

Geometry Computation Subroutine (Cont)

```
      IF(RHOX(I) .EQ. 0.)  GO TO 297                                        00004640
      IF (I .NE. 1) GO TO 298                                               00004650
      GAMA(I) = (3.*(RHOX(I+1) - RHOX(I)) + RHOX(I+1) - RHOX(I+2))/DENMP00004660
      GO TO 305                                                             00004670
  297 GAMA(I)   =   1.E+10                                                  00004680
      GO   TO   305                                                         00004690
  298 IF (I .EQ. N) GO TO 300                                               00004700
      IF (I .EQ. 2) GO TO 299                                               00004710
      IF (I .EQ. N-1) GO TO 299                                             00004720
      GAMA(I) = (RHOX(I-2) - 8. *(RHOX(I-1) -      RHOX(I+1))- RHOX(I+2)00004730
     1 )/DENM                                                               00004740
      GO TO 305                                                             00004750
  299 GAMA(I) = (RHOX(I+1) - RHOX(I-1)) /DENMP                              00004760
      GO TO 305                                                             00004770
  300 GAMA(I) =(3.*(RHOX(I)-RHOX(I-1)) + RHOX(I-2) - RHOX(I-1)) /DENMP  00004780
  305 CONTINUE                                                              00004790
C                                                                           00004800
      IGM = GMI                                                             00004810
      GO TO (510, 510, 310, 500, 500, 500), IGM                             00004820
C                                                                           00004830
  310 DO 370 I = 1,N                                                        00004840
      IF(RHOX(I) .EQ. 0.)  GO TO 340                                        00004850
      GAMRX = GAMA(I) * RHOX(I)                                             00004860
      IF (GAMRX .LE. 1.) GO TO 315                                          00004870
      WT (I) = 0.0                                                          00004880
      WF (I) = 0.0                                                          00004890
      GO TO 370                                                             00004900
  315 WT (I) = (SQRT(1. - GAMRX **2) ) /RHOX(I)                             00004910
  320 DENOM = RHOX(I) * WT (I) * DELSQ * 12.                                00004920
      DENOMP= RHOX(I) * WT (I) * DELSQ                                      00004930
      IF (I .NE. 1) GO TO 325                                               00004940
      WF (I) =(-2.*RHOX(I)+5.*RHOX(I+1)-4.*RHOX(I+2)+RHOX(I+3))/DENOMP  00004950
      GO TO 370                                                             00004960
  325 IF (I .EQ. N) GO TO 335                                               00004970
      IF (I .EQ. 2) GO TO 330                                               00004980
      IF (I .EQ. N-1) GO TO 330                                             00004990
      WF (I) = (RHOX(I-2) - 16. * RHOX(I-1) + 30. * RHOX(I) - 16. *     00005000
     1 RHOX(I+1) + RHOX(I+2) )/ DENOM                                       00005010
      GO TO 370                                                             00005020
  330 WF (I) = (2. * RHOX(I) - RHOX(I-1) - RHOX(I+1)) /DENOMP               00005030
      GO TO 370                                                             00005040
  335 WF (I) =(-2.*RHOX(I)+5.*RHOX(I-1)-4.*RHOX(I-2)+RHOX(I-3))/DENOMP  00005050
      GO   TO   370                                                         00005060
```

Geometry Computation Subroutine (Cont)

```
340 IF(I .EQ. 1)  GO TO 370                                              00005070
345 JTD = 4 * (N/M + 1)                                                  00005080
    IF (ABS(GMI) .GE. 4.0) JTD = 3                                       00005090
    IJTD = JTD - 1                                                       00005100
    IJD = IJTD - 1                                                       00005110
    DO 350 II = 1,IJTD                                                   00005120
    KK = JTD - I + 1                                                     00005130
    I1 = N - KK + 2                                                      00005140
    I2 = N - KK - 3                                                      00005150
    WT(I1) = (-4.*WT(I2) - WT(I2+1) + 2.*WT(I2+2) + 5.*WT(I2+3) + 8.    00005160
   1 *WT(I2+4) )/10.0                                                    00005170
    STAW(II) = I1                                                        00005180
350 CONTINUE                                                             00005190
    WF(N) = WT(N)                                                        00005200
    WFP(1) = WF(JTD-2)                                                   00005210
    WFP(2) = WF(JTD-1)                                                   00005220
    WFP(3) = WF(JTD)                                                     00005230
    WFP(4) = WF(N)                                                       00005240
C                                                                        00005250
    CALL CODIMA (IJD, STAW, WFW, STAP, WFP, 4, -1.0)                     00005260
C                                                                        00005270
    DO 360 II = 1,IJD                                                    00005280
    JTDI = JTD + II                                                      00005290
360 WF(JTDI) = WFW(II)                                                   00005300
C                                                                        00005310
370 CONTINUE                                                             00005320
C                                                                        00005330
    IF (RHOX(1) .NE. 0.0) GO TO 400                                      00005340
    JTD = 4 * (N/M + 1)                                                  00005350
    IF (ABS(GMI) .GE. 4.0) JTD = 3                                       00005360
    IJTD = JTD - 1                                                       00005370
    DO 380 II = 1,IJTD                                                   00005380
    KK = IJTD - II + 1                                                   00005390
    WT(KK) = (8.*WT(KK+1) + 5.*WT(KK+2) + 2.*WT(KK+3) - WT(KK+4) -      00005400
   1 4.*WT(KK+5) )/10.0                                                  00005410
    IF (II .EQ. 1) GO TO 380                                             00005420
    STAW(II-1) = II                                                      00005430
380 CONTINUE                                                             00005440
    WF(1) = WT(1)                                                        00005450
    WFP(1) = WF(1)                                                       00005460
    WFP(2) = WF(JTD)                                                     00005470
    WFP(3) = WF(JTD+1)                                                   00005480
    WFP(4) = WF(JTD+2)                                                   00005490
```

Geometry Computation Subroutine (Cont)

```
      STAP(1) = 1.0
      STAP(2) = JTD
      STAP(3) = JTD + 1
      STAP(4) = JTD + 2
      IJD = IJTD - 1
C
      CALL CODIMA (IJD, STAW, WFW, STAP, WFP, 4, -1.0)
C
      DO 390 II = 2,IJTD
  390 WF(II) = WFW(II-1)
C
  400 NSM = 1
  405 DO 430 I = 3,MLN
      IF (I .NE. 3) GO TO 420
  410 WTH(I) = (-3.*WT(I-2) + 12.*WT(I-1) + 17.*WT(I) + 12.*WT(I+1) -
     1 3.*WT(I+2) )/35.0
      WFE(I) = (-3.*WF(I-2) + 12.*WF(I-1) + 17.*WF(I) + 12.*WF(I+1) -
     1 3.*WF(I+2 ) )/35.0
      GO TO 430
  420 IF (I .EQ. MLN) GO TO 410
      IF (I .EQ. 4)  GO TO 425
      IF (I .EQ. N-3) GO TO 425
      WTH(I) = (-21.*WT(I-4) + 14.*WT(I-3) + 39.*WT(I-2) + 54.*WT(I-1)
     1 + 59.*WT(I) + 54.*WT(I+1) + 39.*WT(I+2) + 14.*WT(I+3) - 21.*
     2 WT(I+4) )/231.0
      WFE(I) = (-21.*WF(I-4) + 14.*WF(I-3) + 39.*WF(I-2) + 54.*WF(I-1)
     1 + 59.*WF(I) + 54.*WF(I+1) + 39.*WF(I+2) + 14.*WF(I+3) - 21.*
     2 WF(I+4) )/231.0
      GO TO 430
  425 WTH(I) = (-2.*WT(I-3) + 3.*WT(I-2) + 6.*WT(I-1) + 7.*WT(I) + 6.*
     1 WT(I+1) + 3.*WT(I+2) - 2.*WT(I+3) )/21.0
      WFE(I) = (-2.*WF(I-3) + 3.*WF(I-2) + 6.*WF(I-1) +7.*WF(I) + 6.*
     1 WF(I+1) + 3.*WF(I+2) - 2.*WF(I+3) )/21.0
  430 CONTINUE
      WTH(1) = (69.*WT(1) + 4.*WT(2) -6.*WT(3) +4.*WT(4) - WT(5) )/70.0
      WFE(1) = WTH(1)
      IF (RHOX(1) .NE. 0.) WFE(1) = (69.*WF(1) + 4.*WF(2) - 6.*WF(3) +
     1 4.*WF(4) - WF(5) )/70.0
      WTH(2) = (2.*WT(1) + 27.*WT(2) + 12.*WT(3) - 8.*WT(4) +2.*WT(5))/
     1 35.0
      WFE(2) = (2.*WF(1) + 27.*WF(2) + 12.* WF(3) -8.*WF(4) +2.*WF(5))/
     1 35.0
      WTH(NN) = (WT(MLN) + WT(NN) + WT(N) )/3.0
```

Geometry Computation Subroutine (Cont)

```
      WFE(NN) = (WF(MLN) + WF(NN) + WF(N) )/3.0
      WTH(N) = (-WT(N-4) + 4.*WT(N-3) - 6.*WT(MLN) + 4.*WT(NN) + 69. *
     1 WT(N) )/70.0
      WFE(N) = WTH(N)
      IF (RHOX(N) .NE. 0.) WFE(N) = (-WF(N-4) + 4.*WF(N-3) - 6.*WF(MLN)
     1 + 4.*WF(NN) + 69.*WF(N) )/70.0
      IF (NSM .EQ. 25) GO TO 510
      NSM = NSM + 1
      DO 435 I = 1,N
      WF(I) = WFE(I)
      WT(I) = WTH(I)
  435 CONTINUE
      GO TO 405
C
  440 DO 460 I = 1,N
      WTH(I) = AO/RCRZ(I)
      WFE(I) = AO/RCRV(I)
      IF (RHOX(I) .FQ. 0.0) GO TO  445
      PRO = (RHOX(I) * WTH(I)) **2
      IF (PRO .GT. 1.0) GO TO  450
      GAMA(I) = SQRT(1.-PRO)/RHOX(I)
      GO TO 460
  445 GAMA(I) = 1.E+10
      GO TO 460
  450 GAMA(I) = 0.0
  460 CONTINUF
C
  500 CONTINUE
  510 WRITE (6,515)  (I, R(I), XSI(I), WFE(I), WTH (I), GAMA(I),
     1 RHOX(I), I = 1,N)
  515 FORMAT (1H-,4X,1HI,9X,4HR(I),12X,5HX(I) ,11X,6HWFF(I),10X,
     1 6HWTH(I)  ,10X,7HGAMA(I),10X,7HRHO(I)  //(I5, 1P6E17.7) )
C                                          SAVE FOURIER LOADS FOR BNDS.
      IF(SUM .EQ. 0.)  GO TO 1000
      DO   520   I = 1,80
      SDA(I + 775)  =  EM5X(I)
  520 SDA(I + 925)  =  EMN5(I)
C
 1000 RETURN
      END
```

Geometry Computation Subroutine (Cont)

```
$IBFTC DLDS                                                                         1
C     SUBROUTINE TO SET UP PN. PFE. PTH. TMP          6J-148  ** LINK 3   00000010
C                                                                          11
      SUBROUTINE  DATLDS (NS)                                              12
C                                                                          13
C  NOMENCLATURE                                                            19
C     PILD        PRESSURE INDICATOR  1=CONSTANTS.  2=FOURIER CMP. KNOWN 00000020
C                 +3=FOURIER SUMMING. SYMMETRICAL.   -3=FOURIER. UNSYM.  00000021
C                 4=SPECIAL FUNCTION (NOT AVAILABLE AT PRESENT)          00000022
C     TIBT        TEMPERATURE IND.. INNER FACE  (AS PILD)                00000023
C     TITP            * * *       . OUTER FACE     * *                   00000024
C                                                                          28
C     TAB(I)      TABLES FOR ALL LOADS AND ALL ENF VALUES                00000029
C     TAB(I)      TABLES FOR ALL LDS. AND ENF'S. DIMENSIONED 200 EACH.   00000029
C                                                                          30
C                                             INDICATOR = 1              00000031
C         TAB(I)     CONSTANT VALUE FOR 1ST ENF                          0,00  32
C         TAB(I+1)  2ND ENF. ETC.                                          33
C                                                                          35
C                                             INDICATOR = 2              00000036
C         TAB(I)    NO. OF ENF'S                                           37
C         TAB(I+1)  ENF VALUE                                              38
C         TAB(I+2)  NO. OF STATIONS                                        39
C         TAB(I+3)  STATION NO. = 1.                                       40
C         TAB(I+4)  LOAD AT STATION ONE                                    41
C         TAB(I+5)F STATION AND LDS.(INTERLACED) LAST STA. NO. = EN      00000042
C         TAB(2*TAB(I+2)+4) LIKE TAB(I+1) FOR 2ND ENF. REPEAT PATTERN    00000043
C                                                                          48
C                                             INDICATOR = 3              00000049
C     ENTH        NO. OF THETAS TO SUM                                     50
C     TAB(I)      TABLES USED FOR DBL. INTRP. PFE, PTH, PN, TBT, TTP     00000051
C         TAB(I)     NO. OF THETA RAYS INCLUDED IN TABLE                 00000052
C         TAB(I+1)  FIRST THETA VALUE (MUST BE ITS LOWEST)               00000053
C         TAB(I+2)  NO. OF STATIONS TO DESCRIBE FIRST THETA RAY          00000054
C            ***  MUST INCLUDE ALL STATIONS LISTED FOR ALL THETAS (20MAX)00000055
C         TAB(I+3)F STATION AND LDS. VALUES ALONG THETA(INTERLACED)      00000056
C         TAB(2*TAB(I+2)+4) LIKE TAB(I+1) FOR 2ND THETA. REPEAT PATTERN  00000057
C                 BUT NOT NECESSARY TO INCLUDE ALL STATIONS              00000058
C                                                                          60
C  ** DINTRP WILL SELECT THE LOWER OR UPPER BOUND WHEN A VALUE IS OFF    00000061
C         AN END OF A THETA RAY.                                           62
C                                                                          69
C     NOSTA      NO. OF STATIONS WHERE LOADS ARE GIVEN  (20 MAXIMUM)     00000070
```

Subroutine to Set Up PN, PFE, PTH, TMP

```
C     STA(I)      STATIONS WHERE LOADS ARE GIVEN                            0000  71
C     VAL(I)      LOADS VALUES                                                    72
C     ENOT        NO. OF TEMP. STA. (20 MAXIMUM) SET TO 0. FOR NO TEMP      00000073
C     STN(I)      STATIONS FOR TBT AND TTP   (ALSO FOR ALL SUMMING)         00000074
C     TBT(I)      FOURIER COMPONENT FOR TEMPERATURE LOAD,  INNER SURFACE 00000075
C     TTP(I)      DITTO .  *  *  *  *  *  *  *  *  *  *   OUTER             00000076
C                                                                                 79
C     THETX(91)  THETA VALUES TO INCLUDE IN SUMMING                         00000080
C     TEMP (20,91)  SUMMING DATA REGION                                           81
C                                                                                 99
      DIMENSION  TAB(1000), PNTB(200), PFETB(200), PTHTB(200), PN(150), 00000100
     1  PFE(150), PTH(150), TLOC(5), STA(20), VAL(20), X(150), TBOTX(2),00000101
     2  THETX(91), TEMP(20,91), PD(20), EMD(20), DLD(1205), ENFOR(4),   00000102
     3  EM5(80), EMN5(80), EM5X(4), EM5N(4), TBOT(200), TTOP(200)       00000103
      DIMENSION  ENT(150), FMT(150),  T(150)                            00000104
C                                                                            139
      EQUIVALENCE      (DLD(1), PILD ),(DLD(2), TIBT  ),(DLD(3), TITP ),00000140
     1(DLD(4), ENTH  ),(DLD(5), TAB  ),                 (DLD(5), PFETB),00000141
     2(DLD(205),PTHTB),(DLD(405),PNTB),(DLD(605), TBOT),(DLD(805),TTOP),00000142
     3(DLD(1005),PSIO),(DLD(1006), PD),(DLD(1026), EMD),(DLD(1046),EM5),00000143
     4(DLD(1126),EMN5),(TLOC(1), PFEX),(TLOC(2), PTHX ),(TLOC(3), PNX ),00000144
     5(TLOC(4), TBOTX),(TLOC(5),TTOPX),                 (NOSTA,  NFE  ) 00000145
C                                                                            159
      EQUIVALENCE      (DA(2),  AO    ),(DA( 9), ENFO  ),(DA(21), ENFOR) 00000160
C                                                                            169
      EQUIVALENCE      (SDA(14), EN   ),(SDA(12), PFLAG),(SDA(20), TLOC),00000170
     1(SDA(626), PFE ),(SDA(776), PTH),(SDA(926),  PN ),                00000171
     2(SDA(2458),EM5X),(SDA(2494),EM5N)                                 0 0- 172
      EQUIVALENCE (SDA(326),ENT), (SDA(476),EMT),(SDA(1226), T)
C     SDA(17), SDA(18), SDA(19) ARE USED FOR LOAD AT A DISCONTINUITY    00000179
C                                                                            199
      COMMON   DA(39), SL2, ELAM2(3), KKF, SQ3, SQ4, SQ6, ENF, IFR, KLM,00000200
     1  SDA(3098), PM(126), ENOT, STN(20), TBT(20), TTP(20)             00000201
C                                                                            209
      N  =  EN                                                               210
      NS  =  NS                                                              211
C                                          TEST FOR FIRST FOURIER COMP.  00000219
      IF(SL2 .NE. 0.)  GO TO 1                                               220
      READ  (11)  PILD, IPRS, ITBT, ITTP, ENTH , (DLD(I), I=5,805,200)  00000225
      GO  TO  300                                                            226
C                                                                            227
    1 DO  2  I = 1,1205                                                      228
    2 DLD(I) = 0.                                                            229
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
      PILD = 1.                                                              230
      TIBT = 1.                                                              231
      TITP = 1.                                                              232
    3 CALL DECRD(DLD)                                                        233
      ITBT  =  TIBT                                                          234
      IPRS = ABS( PILD)                                                      235
      ITTP  =  TITP                                                          236
C                                       SAVE INDICATORS ON FIRST PASS   00000237
      WRITE  (11)  PILD, IPRS, ITBT, ITTP, ENTH, (DLD(I), I=5,805,200)  00000238
      GO  TO  300                                                            240
    4 S5  =  A0 /SQ6                                                         245
C                                                                            248
C                                         CHOOSE PRESSURE PATH          00000249
      GO TO  ( 5, 20, 400, 900), IPRS                                        250
C                                        CONSTANT PRESSURE LOADS        00000254
    5 IF(ENF .NE. ENFO)  GO TO 6                                             257
C                                    SAVE TABLES AND BOUNDARY MATRICES  00000260
      WRITE (11)   (TAB(I),  I = 1,1201)                                0000‸261
      IL  =  1                                                               263
      GO  TO  7                                                              264
    6 IL  =  PFEX + 1.                                                       265
      READ  (11)   (TAB(I),  I = 1,1201)                                0 00‸266
    7 PN  =    S5 * PNTB(IL)                                                 267
      PFE  =   S5 * PFETB(IL)                                                268
      PTH  =   S5 * PTHTB(IL)                                                269
      PFEX  =  IL                                                            270
      DO   8      I = 2,N                                                    271
      PN(I)   =  PN                                                          272
      PFE(I)  =  PFE                                                         274
    8 PTH(I)  =  PTH                                                         276
      GO  TO   95                                                            278
C                                                                            288
C                                       FOURIER COMPONENTS KNOWN        00000289
C     ITB        TAB SUBSCRIPT, INCREMENTED BY PNTB DIMENSION           00000290
C     ISDA       SDA LOCATION, INCREMENTED BY PN DIMENSION              00000291
C     IL         TLOC SUBSCRIPT TO PICK UP NOSTA FOR NEXT ENF /LD,INC=1 00000292
C     NOSTA      NO. OF STATIONS                                             293
C                                                                            299
   20 ITB  =  1                                                              300
      ISDA  =  626                                                           302
      IL  =  1                                                               304
C                                         TEST IF FIRST TIME            00000309
   25 IF(ENF .NE. ENFO)  GO TO 50                                            310
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
      IF(IL .NE. 1)  GO TO 26                                                315
      WRITE (11)   (TAB(I),  I = 1,1201)                                0    320
   26 NOSTA  =  TAB(ITE + 2)                                                 330
      K1  =  3                                                               350
      K2  =  2 * NOSTA + 1                                                   352
      TLOC(IL)  =  K2 + 4                                                    353
C                                            TEST FOR ZERO PRESSURE LOAD  00000354
      IF(NOSTA .EQ. 0)  GO TO 90                                             355
C                                                                            368
C                                        SEPARATE STATIONS AND VALUES     00000369
   30 KO  =  0                                                               370
      DO   35    I = K1,K2,2                                                 380
      KO  =  KO + 1                                                          382
      KX  =  ITB + I                                                         384
      STA(KO)  =  TAB(KX)                                                    386
   35 VAL(KO)  =  TAB(KX+1) * S5                                             388
      GO  TO  60                                                             390
C                                                                            398
C                                            NOT THE FIRST FOURIER COMP.  00000399
   50 READ  (11)   (TAB(I),  I = 1,1201)                                0 0  400
   52 K1  =  TLOC(IL)                                                        410
      KX  =  ITB + K1 - 1                                                    412
      NOSTA  =  TAB(KX)                                                      414
C                                                   TEST FOR ZERO LOAD    00000419
      IF(NOSTA .EQ. 0)  GO TO 89                                             420
      K2  =  2 * NOSTA - 2 + K1                                              422
      TLOC(IL)  =  K2 + 4                                                    424
      GO  TO  30                                                             430
C                                                                            447
C                                        CURVE FIT VALUES TO ALL STATIONS 00000448
C                                                                            449
   60 CALL CODIMA (N,X,SDA(ISDA),  STA,VAL,NOSTA,  1.)                    00000450
C                                            TEST FOR LAST PRESSURE LOAD  00000451
      IF(ITB .EQ. 401) GO TO 95                                              452
C                                        INCREMENT SUBSCRIPTS FOR NEXT P  00000458
C                                                                            459
   80 ITB  =  ITB + 200                                                      460
      ISDA  =  ISDA + 150                                                    462
      IL  =  IL + 1                                                          464
      IF(ENF - ENFO) 52, 26, 52                                              466
C                                                                            477
   89 TLOC(IL)  =  KX + 2                                                    478
C                                                        ZERO PRESSURE    00000479
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
   90 DO  92       I = 1,N                                                        480
      IX  =  ISDA + I - 1                                                         482
   92 SDA(IX)  =  0.                                                              484
      IF(ISDA .NE. 926)  GO TO 80                                                 486
C                                                                                 489
   95 IF(SL2 .EQ. 0.) GO TO 100                                                   490
      IF (PFLAG .GE. 0.)  GO TO 100                                               492
C                                             PRINT LOADS DATA TABLES        00000498
C                                                                                 499
      WRITE (6,97)  NS, (I, PFETB(I), PTHTB(I), PNTB(I), TBOT(I),            00000500
     1  TTOP(I),  I = 1,200)                                                      501
   97 FORMAT(1H1, 40X, 23HLOADS TABLES FOR REGION, I3  /// 10X,1H1, 9X,      00000510
     1  3HPFE, 14X,3HPTH, 14X,2HPN, 14X,4HTBOT, 14X,4HTTOP //                00000511
     2    (I11, 1P5E17.7)  )                                                      512
C                                                                                 513
C                                                    BEGIN TEMPERATURES      00000514
C                                                                                 515
  100 IX  =  1                                                                    516
      ITB  =  601                                                                 519
      ENOT  =  0.                                                                 520
C                                          CHOOSE BOTTOM TEMPERATURE PATH    00000526
      GO TO (105, 120, 800, 900), ITBT                                            527
C                                                                                 528
C                                           CONSTANT TEMPERATURE             00000529
C                                                                                 530
C                                         CHECK WHETHER TAB ALREADY SAVED    00000531
  105 IF(IPRS .LT. 3)  GO TO 106                                                  532
      IF(ENF .NE. ENFO)  GO TO 108                                                533
      WRITE (11)   (TAB(I), I = 1,1201)                                      0 0  534
      GO  TO  107                                                                 536
  106 IF(ENF .NE. ENFO)  GO TO 109                                                540
  107 TBOTX(IX)  =  1.                                                            542
      IL  =  ITB                                                                  544
      GO  TO  110                                                                 546
C                                                                                 549
  108 READ (11)   (TAB(I), I = 1,1201)                                            550
  109 TBOTX(IX)  =  TBOTX(IX) + 1.                                                552
      IL  =  IFIX( TBOTX(IX) ) + ITB - 1                                     0.00.554
C                                         TEST FOR ZERO TEMPERATURE          00000555
  110 IF(TAB(IL) .EQ. 0.)  GO TO 116                                         - 0  556
      DO  115     I = 1,KS                                                        570
      II  =  I + (ITB - 601) /10                                                  572
  115 TBT(II)  =  TAB(IL)                                                         574
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
      GO  TO  150                                                           00000575
C                                          WERE BOTH TEMPERATURES ZERO      00000576
  116 IF(IX .EQ. 1)  GO TO 118                                              00000577
      IF(ENOT .EQ. 0.)  GO TO 850                                           00000578
      DO   117    I = 1,KS                                                  00000580
  117 TTP(I)   =  0.                                                        00000581
      GO  TO  850                                                           00000582
  118 ENOT   =   0.                                                         00000584
      GO  TO  200                                                           00000585
C                                                                           00000588
C                                   TEMPERATURE. FOURIER COMPONENTS KNOWN   00000589
  120 IF(IPRS .LT. 3)  GO TO 126                                            00000600
      IF(ENF .NE. ENFO)  GO TO 128                                          00000602
      WRITE (11)    (TAB(I), I = 1,1201)                                    00000604
      GO  TO  127                                                           00000606
  126 IF(ENF .NE. ENFO)  GO TO 129                                          00000610
  127 NOSTA   =  TAB(ITB + 2)                                               00000612
C                                          TEST FOR ZERO TEMPERATURE        00000613
      IF(NOSTA .EQ. 0)  GO TO 116                                           00000614
      K1   =   3                                                            00000616
      K2   =   2 * NOSTA + 1                                                00000618
      GO  TO  140                                                           00000620
  128 READ (11)    (TAB(I), I = 1,1201)                                     00000630
  129 K1   =   TBOTX(IX)                                                    00000632
      KX   =   ITB + K1 - 1                                                 00000634
      NOSTA   =   TAB(KX)                                                   00000636
      IF(NOSTA .EQ. 0)  GO TO 116                                           00000638
      K2   =   2 * NOSTA - 2 + K1                                           00000640
  140 TBOTX(IX)   =   K2 + 4                                                00000642
C                                                                           00000648
C                                          SEPARATE STATIONS AND VALUES     00000649
      K0   =   0                                                            00000650
      DO   142     I = K1,K2,2                                              00000652
      KO   =   KO + 1                                                       00000654
      KX   =   ITB + I                                                      00000656
      STA(KO)   =   TAB(KX)                                                 00000658
  142 VAL(KO)   =   TAB(KX+1)                                               00000660
  150 II   =   1 + (ITB - 601) /10                                          00000665
C                                                                           00000668
C                                          FIT VALUES TO 20 TEMP. STATIONS  00000669
      CALL CODIMA (KS,STN,TBT(II),STA,VAL,KO,  1.)                          00000670
C                                          WERE BOTH TEMPERATURES NON-ZERO  00000671
      IF(IX .EQ. 1)  GO TO 157                                              00000672
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
      IF(ENOT .NE. 0.)  GO TO  850                                              674
      DO   155   I = 1,KS                                                       676
  155 TBT(I)  =  0.                                                             677
C                                                                               679
  157 ENOT  =  KS                                                               680
      GO TO (200,850), IX                                                       682
C                                                                               686
  200 IX  =  2                                                                  690
      ITB  =  601                                                               692
C                                         CHOOSE TOP TEMPERATURE PATH   00000693
      GO TO (106, 126, 830, 900), ITTP                                          694
C                                         SET UP TEMPERATURE STATIONS   00000978
C                                                                               979
  300 INC  =  (N/19) + 1                                                        980
      KS  =  1                                                                  982
      DO   312   I = 1,N,INC                                                    984
      STN(KS) =  I                                                              986
  312 KS = KS + 1                                                               988
      IF(STN(KS-1).GE. EN)  GO TO 314                                   0       990
      STN(KS) =  EN                                                             992
      GO  TO   320                                                              994
  314 KS = KS - 1                                                               996
C                                     FORM STATION NO. COLUMN           00000999
  320 DO  325    I = 1,N                                                       1000
  325 X(I)  =  I                                                               1002
C                                                                              1008
C                                     MOVE BND. MATRICES TO DLD DATA    00001009
      DO   330   I = 1,80                                                      1010
      EMS(I)  =  SDA(I + 775)                                                  1012
  330 EMNS(I)  = SDA(I + 925)                                                  1014
      GO  TO  4                                                                1030
C                                                                              1099
C                                              FOURIER  SUMMING         00001100
C                                                                              1109
  400 ITB  =  1                                                                1110
      ISDA  =  626                                                             1111
      INDC  =  PILD                                                            1112
      IGO  =  1                                                                1113
      S3  =  AO /SQ6                                                           1114
  401 NTH  =  ENTH                                                             1118
C                          SET UP THETAS FOR SYMMETRICAL OR UNSYM.      00001159
      IF(INDC .LT. 0 ) GO TO 405                                        0 0 1160
      DELTH  =  3.1415927 /(ENTH - 1.)                                  00001162
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
      S2  =  S3 /(ENTH - 1.) /2.                                        0 001164
      GO  TO  407                                                          1166
C                                           SIN PART NOT AVAILABLE      00001169
  405 DELTH  =  6.2831853 /ENTH                                           0 1170
      S2  =  S3 /ENTH                                                      1172
  407 DO   410   I = 1,NTH                                                 1174
      EI  =  I - 1                                                         1176
  410 THETX(I)  =  EI * DELTH * 57.295779                               00001178
C                                              TEST FOR ZERO LOAD       00001199
  420 IF(TAB(ITB) .EQ. 0.) GO TO (790,116), IGO                         00001200
C                                                                          1209
      IF(SL2 .EQ. 0.)  GO TO  510                                       - 0 1210
C                                        SET UP STATIONS TO SUM         00001219
      NFE    =   TAB(ITB+2)                                                1220
      K1  =  3                                                             1221
      K2  =  2 * NFE   + 1                                                 1222
      K0  =  0                                                             1223
      DO   428   I = K1,K2,2                                               1230
      K0  =  K0 + 1                                                        1232
      KX  =  ITB + I                                                       1234
  428 STA(K0)  =  TAB(KX)                                                  1236
C                                                                          1340
C                                              FORM SUMMING MATRIX      00001349
  430 DO  440     I = 1,NFE                                                1350
      DO  440     J = 1,NTH                                                1360
  440 TEMP(I,J)  =  DINTRP( THETX(J), STA(I), TAB(ITB) )                00001370
C                                                                          1380
      IF( PFLAG ) 450,460,460                                              1390
C                                                                          1399
C                                     PRINT SUMMING AREA ON NEG. IND.  00001400
  450 WRITE (6,451)NS,ITB,((TEMP(I,J), I = 1,NFE),  J = 1,NTH)          00001410
  451 FORMAT(/// 10X, 11HFOR  REGION, I3, 27H THE SUMMING AREA FOR ITB =00001420
     1 I4, 4H WAS // (1P8E13.4)  )                                      0 0 1430
C                                                                          1440
  460 WRITE(11)ITB,NFE,((TEMP(I,J), I = 1,NFE), J = 1,NTH),             00001450
     1                (DLD(I), I = 1005,1205), (STA(I), I = 1,NFE)      00001451
      GO  TO  520                                                          1460
C                                                                          1470
  510 READ(11) ITB,NFE,((TEMP(I,J), I = 1,NFE), J = 1,NTH),             00001480
     1                (DLD(I), I = 1005,1205), (STA(I), I = 1,NFE)      00001481
C                                                 ZERO THETA AND VAL    00001499
  520 THETA = 0.                                                           1500
      DO   530   I = 1,NFE                                                 1510
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
  530 VAL(I)  =  0.
C
C                                      FORM FOURIER COMP. AT THETA=0. STATIONS
C
  600 DO   670   J = 1,NTH
      IF(ISDA .NE. 776)  GO TO 620
      IF(ENF .EQ. 0.)  GO TO 790
  610 S1  =  SIN(ENF * THETA)
      GO  TO  621
  620 S1  =  COS(ENF * THETA)
  621 IF(J - 1) 623,622,623
  622 S5  =  1.
      GO  TO  630
  623 IF(J - NTH) 624,622,624
  624 IF(INDC .LT. 0)   GO TO 622
  625 S5  =  2.
C
  630 DO   650   I = 1,NFE
  650 VAL(I)  =  VAL(I) + TEMP(I,J) * S1 * S5
  670 THETA  =  THETA + DELTH
C
      IF( ENF ) 710,700,710
  700 S1  =  S2
      GO  TO  750
  710 S1  =  2. * S2
C
  750 DO  760    I = 1,NFE
  760 VAL(I)  =  VAL(I) * S1
C
      IF(ITB .GT. 401) GO TO 810
C                                              FIT PRESSURES TO ALL STATIONS
      CALL CODIMA (N,X,SDA(ISDA),  STA,VAL,NFE,  1.)
C                                            INCREMENT SUBSCRIPTS FOR NEXT P
  780 ITB  =  ITB + 200
      ISDA  =  ISDA + 150
      IF(ITB - 401) 420,420,95
C                                            FILL A PRESSURE LOAD WITH ZERO
  790 DO  792    I = 1,N
      IX  =  ISDA + I - 1
  792 SDA(IX)  =  0.
      IF(ISDA .NE. 926)  GO TO 780
      GO  TO   95
C
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
C                                          SET UP INDICES FOR TEMPERATURES 00001938
C                                                                          00001939
  800 IGO  =  2                                                            00001940
      INDC  =  ITRT                                                        00001942
      S3  =  1.                                                            00001944
      GO  TO  401                                                          00001948
C                                                                          00001969
  810 KO = NFF                                                             00001970
      GO TO  150                                                           00001976
C                                                                          00002009
  830 IGO  =  2                                                            00002010
      INDC  = ITTP                                                         00002012
      GO  TO  401                                                          00002014
  850 IF (ENOT .NE. 0.) GO TO 863                                          00002015
      DO  862 I = 1,150                                                    00002016
      T(I) = 0.0                                                           00002017
      ENT(I) = 0.0                                                         00002018
  862 EMT(I) = 0.0                                                         00002019
C                                                                          00002020
  863 IF (PFLAG .GE. 0.)  GO TO 1000                                       00002031
      WRITE (6,851)          NS, (STN(I), TBT(I), TTP(I), I = 1,KS)        00002032
  851 FORMAT(1H1,34X, 10HFOR REGION , I3,27H THE TEMPERATURE LOADS WERE    00002040
     1 //40X,4HSTN., 7X,4HTBOT, 9X,4HTTOP // (0PF45.1, 1P2E13.4 ) )        00002041
      GO  TO  1000                                                         00002045
C                                                                          00002059
  900 WRITE (6,901)                                                        00002060
  901 FORMAT(/// 49HTHERE ARE NO SPECIAL FUNCTION ROUTINES AVAILABLE. )    00002061
      CALL EXIT                                                            00002062
      STOP                                                                 00002063
C                              SET UP LOAD AT DISCONTINUITY                00002069
 1000 IF(ENF .NE. ENFO)  GO TO 1009                                        00002070
      SDA(17)   =   PSIO                                                   00002080
      SDA(18)   =   PD(1)                                                  00002082
      SDA(19)   =   EMD(1)                                                 00002084
      IF(NS .NE. 1)     GO TO 1050                                         00002086
      ENFOR(4)   =   -1.                                                   00002088
      GO  TO  1050                                                         00002090
C                                                                          00002099
 1009 IF(NS .NE. 1)  GO TO 1011                                            00002100
 1010 ENFOR(4)   =   ENFOR(4) - 1.                                         00002102
 1011 IX   =  - ENFOR(4)                                                   00002104
      SDA(18)   =   PD(IX)                                                 00002106
      SDA(19)   =   EMD(IX)                                                00002108
```

Subroutine to Set Up [illegible]N, PFE, PTH, TMP (Cont)

```
C                                                                      00002119
      K  =  4 *(IX - 1)                                                00002120
      DO   1020  I = 1,4                                               00002122
      L  =  K + I                                                      00002124
      EM5X(I)  =  EM5(L)                                               00002126
 1020 EM5N(I)  =  EMN5(L)                                              00002128
C                                           ZERO LOADS AREAS           00002130
C                                                                      00009999
 1050 RETURN                                                           00010000
      END                                                              00012000
```

Subroutine to Set Up PN, PFE, PTH, TMP (Cont)

```
$IBFTC DNTP
C     DOUBLE INTERPOLATION FUNCTION SUBROUTINE               J.L. FICK
C   ARGUMENTS
C     X      USED TO DETERMINE WHICH TABLE TO USE (WHICH CURVE OF FAMILY)
C     Y      ARGUMENT USED AS X COORDINATE OF POINTS ON CURVE
C     TAB(1)      NO. OF TABLES (NO. OF CURVES IN FAMILY)
C     TAB(2)      NO. TO REPRESENT FIRST CURVE. MUST BE ITS LOWEST VALUE
C     TAB(3)      NO. OF ARGUMENTS IN FIRST TABLE (POINTS ALONG CURVE)
C     TAB(4),ETC.     X AND Y VALUES ALONG CURVE (INTERLACED)
C     TAB(2*TAB(3)+4)      LIKE TAB(2) FOR 2ND CURVE.  THIS IS FOLLOWED
C     BY ITS NO. OF PTS., VALUES, AND REPEATED THE NO. OF TIMES NECES-
C     SARY BASED ON THE NO. OF TABLES LISTED IN TAB(1)
C
      FUNCTION DINTRP(X,Y,TAB)
      DIMENSION TAB(1)
      N = TAB + .5
      J = 0
      K = 0
    3 DO 50 I=1,N
C     M SELECTS ONE OF FAMILY OF CURVES EQUAL TO OR ABOVE X VALUE
      M = I+J
C     MU REPRESENTS NEXT LOWEST CURVE IN FAMILY
      MU = I+K-1
      IF(TAB(M+1)-X) 20,10,4
    4 IF(I-1) 5,5,7
   10 DINTRP=FNTERP(Y,TAB(M+2))
      RETURN
    7 Z2 = ENTERP(Y,TAB(M+2))
      Z1 = ENTERP(Y,TAB(MU+2))
      DINTRP = Z1 + (X - TAB(MU+1)) * (Z2 - Z1) / (TAB(M+1) - TAB(MU+1))
      RETURN
   20 K = J
   50 J =  INT (TAB(M+2) + .5) * 2 + 1 + J
    5 MP1 = M + 1
    6 WRITE (6, 30)  X, (TAB(L), L=1,MP1)
   30 FORMAT(//5X, 43HARGUMENT EXCEEDS EXTENT OF TABLE IN DINTRP. /10X,
     1 10HARGUMENT =,1PE12.4 /10X, 12HTABLE VALUES, 5X,1P6E12.4 /
     2   (27X, 6E12.4) )
      CALL EXIT
      STOP
      END
$*
```

Double Interpolation Function Subroutine

```
$IBFTC FNTP
C     LINEAR  INTERPOLATION  SUBROUTINE **ENTERP**             6J-997      00000001
C                                                                                 2
C     SELECTS THE VALUE AT EITHER END OF TABLE WHEN ARGUMENT EXCEEDS      00000003
C     LIMIT, THEN CONTINUES                                                       4
C                                                                                 5
C  SUBROUTINE ARGUMENTS                                                           6
C     X          VALUE TO LOOK UP IN TABLE                                        7
C     TAB(1)     NO. OF PAIRS OF ARGUMENTS AND VALUES IN TABLE            00000008
C     TAB(2),ETC ARGUMENTS AND FUNCTIONS INTERLACED                       00000  9
C                                                                                19
      FUNCTION ENTERP (X,TAB)                                                    20
C                                                                                24
      DIMENSION TAB(101)                                                         25
      IF (TAB) 9,9,8                                                             30
    9 ENTERP = - TAB                                                             35
      RETURN                                                                     40
    8 N = TAB                                                                    45
      DO 5 I=1,N                                                                 50
    1 IF (TAB(2*I)-X) 5,4,3                                                      55
    3 IF (I-1) 6,6,7                                                             60
    7 ENTERP = TAB(2*I-1) + (X-TAB(2*I-2)) * (TAB(2*I+1) - TAB(2*I-1))    00000065
     V    / (TAB(2*I) - TAB(2*I-2))                                              70
      RETURN                                                                     80
    4 ENTERP = TAB(2*I+1)                                                        85
      RETURN                                                                     90
    5 CONTINUE                                                                   95
      M = 2*N+1                                                                 100
      K = M                                                                     101
  105 WRITE  ( 6,10)    X, TAB(K)                                               105
   10 FORMAT (// 10X, 39HLIMITS OF TABLE EXCEEDED BY ARGUMENT = 1PE12.4 00000110
     1 / 10X, E12.4, 24H = VALUE USED FROM TABLE   )                      00000111
      ENTERP = TAB(K)                                                           115
      RETURN                                                                    120
    6 M = 2*N+1                                                                 130
      K = 3                                                                     140
      GO TO 105                                                                 150
      END                                                                       160
```

Linear Interpolation Subroutine **ENTERP**

```
$IBFTC DLYR                                                                     00000001
C     SUBR. TO SET UP D, EK, ENT, EMT, E1, T, ALF  (SECTION PROPERTIES) 00000010
C                                                    6J-148   ** LINK 4   00000011
      SUBROUTINE  DATLYR( NS )                                          00000020
C                                                                       00000029
C  NOMENCLATURE                                                         00000030
C     ELAY        NO. OF LAYERS  (6 MAXIMUM)                            00000031
C     STRIX       LAYER NO. FOR 2ND STRESS PRINT            SDA(13)     00000032
C     EIFH        THICKNESS INDICATOR +1 = CONSTANT ALL STATIONS IN A   00000033
C                 LAYER,     -1 = DISCRETE VALUES GIVEN AT THSTA STATIONS00000034
C     ENOTH       NO. OF THSTA, STATIONS FOR THICKNESSES GIVEN IN TH    00000036
C     THSTA(20)   STATION NUMBERS AT WHICH THICKNESSES ARE GIVEN.       00000037
C     TH(20,6)    THICKNESSES AT STATIONS, LAYERS                       00000038
C     ENMAT       NO. OF MATERIALS FOR ELASTIC MOD. AND THERMAL EXPAN.  00000039
C     EMAT(6)     MATERIAL INDICATOR /LAYER  (1, 2, OR 3)               00000040
C     POIS(6)     POISSONS RATIO /LAYER                                 00000041
C                                                                       00000049
C     ENE1,2,3    NO. OF YOUNG'S MODULI FOR EACH MATERIAL               00000050
C     YM1,2,3(10) YOUNGS MODULUS (E)          TMPE1,2,3(10)   TEMP.     00000051
C     ENA1,2,3    NO. OF THERMAL EXPANSION COEF. FOR EACH MATERIAL      00000055
C     ALF1,2,3    THERMAL EXPANSION COEF.     TMPA1,2,3(10)   TEMP.     00000056
C     ENOGR       NO. OF GSTA, STATIONS FOR GRADIENTS GIVEN IN GR       00000057
C     GSTA(10)    TEMPERATURE GRADIENT STATIONS  (SAME FOR EA. INTERFACE)00000058
C     GR(10,5)    GRADIENTS AT GSTA STATIONS AND INTERNAL INTERFACES    00000059
C                                                                       00000060
C     ENOT        NO. OF TSTA, STATIONS FOR TEMPERATURES                00000061
C     TSTA(20)    STATION NUMBERS AT WHICH TEMPERATURES ARE GIVEN       00000062
C     TBOT(20)    TEMPERATURES ON INNER SURFACE                         00000063
C     TTOP(20)    TEMPERATURES ON OUTER SURFACE                         00000064
C                                                                       00000068
C     STA(40)     COMBINED TSTA AND THSTA                               00000069
C     EI(40,6)    INNER MODULUS /STA /ELAY                              00000070
C     EO(40,6)    OUTER MODULUS                                         00000071
C     ALFI(40,6)  INNER COEF. OF THERMAL EXPANSION                      00000072
C     ALFO(40,6)  OUTER COEF. OF THERMAL EXPANSION                      00000073
C     TMP(40,7)   TEMP. /STA /(ELAY+1.)                                 00000074
C     THK(40,6)   THICKNESSES /STA /ELAY                                00000075
C                                                                       00000099
      DIMENSION  DNA(150), TSTA(20), THSTA(20), TH(20,6), EMAT(6),      00000100
     1 STA(40), POIS( 6), YM1(10), YM2(10), YM3(10), ALF1(10), ALF2(10),00000101
     2 ALF3(10), EI(40,6), EO(40,6), ALFI(40,6), ALFO(40,6), TMP(40,7), 00000102
     3 THK(40,6), DNAX(40,7), D(150), EK(150), ENT(150), EMT(150),      00000103
     4 X(150), TX(150), E1(150), TMPE1(10), TMPE2(10), TMPE3(10),       00000104
     5 TMPA1(10), TMPA2(10), TMPA3(10), DAL(345), TT(150), ALF(150),    00000105
     6 ENE1(1), GSTA(10), GR(10,5), DNA2(150), E2(150), T2(150)         00000106
C                                                                       00000199
      EQUIVALENCE    (DAL(1),  ELAY ),(DAL(2), STRIX ),(DAL(3), EIFH  ),00000200
```

Subr. to Set Up D, EK, ENT, EMT, E1, T, ALF (Section Properties)

```
     1                (DAL(4), ENOTH ),(DAL(5),  THSTA),(DAL(25),  TH  ),00000201
     2                (DAL(145),ENMAT),(DAL(146), EMAT),(DAL(152), POIS),00000202
     3                (DAL(158), FNE1),(DAL(159),TMPF1),(DAL(169), YM1 ),00000203
     4                (DAL(179), ENE2),(DAL(180),TMPF2),(DAL(190), YM2 ),00000204
     5                (DAL(200), ENE3),(DAL(201),TMPE3),(DAL(211), YM3 ),00000205
     6                (DAL(221), ENA1),(DAL(222),TMPA1),(DAL(232), ALF1),00000206
     7                (DAL(242), ENA2),(DAL(243),TMPA2),(DAL(253), ALF2),00000207
     8                (DAL(263), ENA3),(DAL(264),TMPA3),(DAL(274), ALF3),00000208
     9                (DAL(284),ENOGR),(DAL(285), GSTA),(DAL(295),  GR ) 00000209
C                                                                        00000299
      EQUIVALENCE     (SDA(1),  EX  ),(SDA(2), GEOMI ),(SDA(3), SPRL ),00000300
     1(SDA(4),  UK    ),(SDA(5),  VK  ),(SDA(6),  WK    ),(SDA(7),  EMK ),00000301
     2(SDA(8),  PSI   ),(SDA(9),  ECX ),(SDA(10), BCIT  ),(SDA(11), BCIB),00000302
     3(SDA(12), PFLAG),(SDA(13), STRI),(SDA(14),   EN  ),(SDA(15), DEL ),00000303
     4(SDA(20), TLOC ),                                (SDA(25), POI ),00000304
     1(SDA(26),  D   ),(SDA(176), EK ),(SDA(326), ENT  ),(SDA(476), EMT),00000311
     2(SDA(626), PFE ),(SDA(776), PTH),(SDA(926), PN   ),(SDA(1076), E1),00000312
     3(SDA(1226), TX ),(SDA(1376),ALF),(SDA(1526), DNA),(SDA(2498),XSI),00000313
     4(SDA(1676),RHOX),(SDA(1826),GAMA),(SDA(1976), R),(SDA(2126),WTHD),00000314
     5(SDA(2276),WFE ),(SDA(2426),EM1),(SDA(2442), EM3),(SDA(2458),EM5),00000315
     6(SDA(2462),EM1N),(SDA(2478),EM3N),(SDA(2494),EM5N),(SDA(2649),E2),00000316
     7(SDA(2648),POI2),(SDA(2799), T2),(SDA(2949),DNA2)                  00000317
C                                                                        00000339
      EQUIVALENCE     (DA(1),  EKK  ),(DA(2),   AO   ),(DA(3),  HO    ),00000340
     1(DA(4),    EO   ),(DA(5),  SIGO ),(DA(6),  PIXI  ),(DA(7), PTHI  ),00000341
     2(DA(8),   SUM   ),(DA(9),  ENFO ),(DA(10), ENFI  ),(DA(21), ENFOR),00000342
     3(DA(25), THETA )                                                   00000343
C                                                                        00000349
      COMMON    DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,      00000350
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                                00000351
      COMMON   SDA(3098), PM(126), ENOT, TSTA, TBOT(20), TTOP(20)        00000360
C                                                                        00000369
      NS  =  NS                                                          00000370
C                                            TEST FOR FIRST PASS         00000371
      IF(SL2 .NE. 0.)  GO TO 1                                           00000372
C                                            READ DATA FROM TAPE  4      00000379
      READ  (4)     DAL                                                  00000380
      GO  TO  15                                                         00000382
C                                                                        00000389
    1 DO   2     I = 1,345                                               00000390
    2 DAL(I)   =  0.                                                     00000392
C                                                                        00000399
      CALL  DECRD (DAL)                                                  00000400
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
C                                                                      00000409
      IF(ENE1 .EQ. 0.)  GO TO 8                                        00000410
C                                        SAVE MATERIAL PROPERTIES IN PM 00000419
      DO   5      I = 1,126                                            00000420
    5 PM(I)   =  ENE1(I)                                               00000422
      GO  TO  12                                                       00000424
C                                    MOVE MATERIAL PROPERTIES FROM PM  00000439
    8 DO   9      I = 1,126                                            00000440
    9 ENE1(I)   =  PM(I)                                               00000442
C                                              WRITE DATA ON TAPE  4   00000449
   12 WRITE  (4)     DAL                                               00000450
C                                    CHANGE FLOATING DATA TO INTEGERS 00000508
   15 N  =  EN                                                         00000509
      MT  =  ENOT                                                      00000510
      MTH  =  ENOTH                                                    00000512
      NMAT  =  ENMAT                                                   00000514
      NLAY  =  ELAY                                                    00000516
      NOGR  =  ENOGR                                                   00000517
      NLAY1  =  NLAY + 1                                               00000518
      STRI  =  STRIX                                                   00000519
      INE1  =  ENE1                                                    00000520
      INE2  =  ENE2                                                    00000521
      INE3  =  ENE3                                                    00000522
      INA1  =  ENA1                                                    00000523
      INA2  =  ENA2                                                    00000524
      INA3  =  ENA3                                                    00000525
      POI  =  POIS                                                     00000526
      S2  =  1. + POI                                                  00000527
      S1  =  1. - POI                                                  00000528
C                          SET UP COMMON THICKNESS AND TEMP. STATIONS  00000529
      IF(E(FH .LT. 0.) GO TO 19                                        00000530
      MTH  =  2                                                        00000531
      THSTA  =  1.                                                     00000532
      THSTA(2)  =  EN                                                  00000533
C                                    ARE BOTH TOP AND BOTTOM TEMP=0.  00000537
   19 IF(MT .NE. 0) GO TO 22                                           00000538
C                                                                      00000539
      M  =  MTH                                                        00000540
      DO  20       I = 1,M                                             00000542
   20 STA(I)   = THSTA(I)                                              00000544
      GO  TO   100                                                     00000546
   22 CALL STCOMB (MT, MTH, M, TSTA, THSTA, STA)                       00000550
C                                                                      00000558
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
C                                          SET TEMPERATURE VALUES IN TMP   00000559
      IF(NLAY •EQ• 1)  GO TO 40                                            00000560
      IX  =  NLAY - 1                                                      00000563
      IF(NOGR •NE• 1)  GO TO 30                                            00000564
C                                 CONSTANT GRADIENT ALONG ALL INTERFACES   00000567
      GSTA(1)  =  1•                                                       00000568
      GSTA(2)  =  EN                                                       00000570
      NOGR  =  2                                                           00000572
C                                                                          00000573
C                      RE-ARRANGE GRADIENTS• PERMITS CONST• TO ENTER CONSECUT•00000574
      I  =  IX                                                             00000576
   25 DO   26     J = 1•2                                                  00000580
   26 GR(J•I)  =  GR(I•1)                                                  00000582
      I  =  I - 1                                                          00000586
      IF(I •NE• 0)  GO TO 25                                               00000588
C                                                                          00000589
   30 DO   31     K = 1•IX                                                 00000590
C                               FIT TEMP• AND GRADIENTS TO COMMON STATIONS 00000591
   31 CALL CODIMA( M•STA•TMP(1•K+1)•   GSTA•GR(1•K)•NOGR•  1•)             00000592
C                                                                          00000595
   40 CALL CODIMA( M•STA•TMP(1•1)•    TSTA•TBOT•MT•  1•)                   00000596
      CALL CODIMA( M•STA•TMP(1•NLAY1)•     TSTA•TTOP•MT•  1•)              00000598
      IF(NLAY •EQ• 1)  GO TO 100                                           00000600
C                                                                          00000609
      DO   50     K = 1•IX                                                 00000610
      DO   50     L = 1•M                                                  00000612
   50 TMP(L•K+1)  =  TMP(L•K+1) * (TMP(L•NLAY1) - TMP(L•1)) + TMP(L•1)     00000614
C                                                                          00000618
C                                          SET THICKNESSES IN THK REGION   00000619
  100 IF(EIFH •LT• 0•) GO TO 150                                           00000620
C                                                                          00000639
  140 DO  145     K = 1•NLAY                                               00000640
      J  =  NLAY + 1 - K                                                   00000641
      DO  145     I = 1•M                                                  00000642
  145 THK(I•J)  =  TH(J•1)                                                 00000644
      GO  TO  200                                                          00000646
C                                                                          00000649
  150 IF(M - MTH)152•160•152                                               00000650
  152 DO   155    K = 1•NLAY                                               00000652
  155 CALL CODIMA( M•STA•THK(1•K)• THSTA•TH(1•K)•MTH•  1•)                 00000654
      GO  TO  200                                                          00000656
  160 DO  165     I = 1•M                                                  00000658
      DO  165     K = 1•NLAY                                               00000660
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
  165 THK(I,K)  =  TH(I,K)                                                     00000662
C                                                                              00000699
C                                      SET EI, EO, ALFI, ALFO  /LAYER          00000729
  200 DO   300   K = 1,NLAY                                                    00000730
      IXX  =  EMAT(K)                                                          00000732
      IF(IXX - NMAT) 209,209,600                                               00000733
  209 IF (K-1) 210,230,210                                                     00000734
  210 IF(EMAT(K) - EMAT(K-1)) 230,211,230                                      00000736
  211 IF(MT .EQ. 0)  GO TO 230                                                 00000738
  212 DO  215    I = 1,M                                                       00000740
      EI(I,K)  =  EO(I,K-1)                                                    00000742
  215 ALFI(I,K)  =  ALFO(I,K-1)                                                00000744
      GO TO (245,255,265),IXX                                                  00000746
C                                                                              00000759
  230 GO TO (237,247,257),IXX                                                  00000760
C                            SET EI AND EO CONSTANT FOR ZERO TEMPERATURES      00000761
  237 IF(MT .NE. 0)  GO TO 240                                                 00000762
      YMX  =  YM1                                                              00000763
  238 DO  239    KK = 1,M                                                      00000765
      EI(KK,K)  =  YMX                                                         00000766
  239 EO(KK,K)  =  YMX                                                         00000767
      GO  TO  300                                                              00000768
  240 CALL CODIMA (M,TMP(1,K),EI(1,K),      TMPE1,YM1,INE1, 1.)                00000770
      CALL CODIMA (M,TMP(1,K),ALFI(1,K),    TMPA1,ALF1,INA1, 1.)               00000772
  245 CALL CODIMA (M,TMP(1,K+1),EO(1,K),    TMPE1,YM1,INE1, 1.)                00000774
      CALL CODIMA (M,TMP(1,K+1),ALFO(1,K), TMPA1,ALF1,INA1, 1.)                00000776
      GO  TO  300                                                              00000778
C                                                                              00000786
  247 IF(MT .NE. 0)  GO TO 250                                                 00000787
      YMX  =  YM2                                                              00000788
      GO  TO  238                                                              00000789
  250 CALL CODIMA (M,TMP(1,K),EI(1,K),      TMPE2,YM2,INE2, 1.)                00000790
      CALL CODIMA (M,TMP(1,K),ALFI(1,K),    TMPA2,ALF2,INA2, 1.)               00000792
  255 CALL CODIMA (M,TMP(1,K+1),EO(1,K),    TMPE2,YM2,INE2, 1.)                00000794
      CALL CODIMA (M,TMP(1,K+1),ALFO(1,K), TMPA2,ALF2,INA2, 1.)                00000796
      GO  TO  300                                                              00000798
C                                                                              00000806
  257 IF(MT .NE. 0)  GO TO 260                                                 00000807
      YMX  =  YM3                                                              00000808
      GO  TO  238                                                              00000809
  260 CALL CODIMA (M,TMP(1,K),EI(1,K),      TMPE3,YM3,INE3, 1.)                00000810
      CALL CODIMA (M,TMP(1,K),ALFI(1,K),    TMPA3,ALF3,INA3, 1.)               00000812
  265 CALL CODIMA (M,TMP(1,K+1),EO(1,K),    TMPE3,YM3,INE3, 1.)                00000814
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
      CALL CODIMA (M,TMP(1,K+1),ALFO(1,K), TMPA3,ALF3,INA3, 1.)         00000816
  300 CONTINUE                                                          00000818
C                                                                       00000819
C                                  SET INDICATOR FOR TEMP. LD. CHANGE ONLY 00000820
      MSP  =  1                                                         00000822
      IF(PTHI .LE. 0.)  GO TO 304                                       00000824
  301 MSP  =  0                                                         00000826
      DO  302    I = 1,M                                                00000830
      K  =  STA(I)                                                      00000832
  302 DNAX(I,1)   =   DNA(K)                                            00000834
      GO  TO  329                                                       00000836
C                                                                       00000847
C                                            COMPUTE SECTION PROPERTIES 00000848
C                                                                       00000849
  304 DO   320    I = 1,M                                               00000850
      S13  =  0.                                                        00000851
      S11  =  0.                                                        00000852
      S12  =  0.                                                        00000853
      S10  =  0.                                                        00000854
      DO   310    K = 1,NLAY                                            00000856
      IF(K .EQ. 1)  GO TO 305                                           00000857
      S12  =  THK(I,K) * (EO(I,K) + EI(I,K)) * S13 * 3.0                00000858
  305 S10  =  S10 + THK(I,K) **2 *(2.*EO(I,K) + EI(I,K)) + S12          00000860
      S13  =  S13 + THK(I,K)                                            00000861
  310 S11  =  S11 + THK(I,K)      *(EO(I,K) + EI(I,K))                  00000862
  320 DNAX(I,1) =   - S10 /3. /S11                                      00000863
C                                         DNAX = DIST. TO NEUTRAL AXIS  00000864
  329 DO   330    I = 1,M                                               00000866
      DO   330    K = 2,NLAY1                                           00000868
  330 DNAX(I,K)   =   DNAX(I,K-1) + THK(I,K-1)                          00000870
C                                                                       00000899
  335 S5   =   .5 / EO / HO                                             00000900
      S6   =   S5 /6. /HO **2                                           00000901
      S7   =   1. / HO / SIGO                                           00000902
      S8   =   AO * S7 / HO **2                                         00000903
      S7   =   S7 /12.                                                  00000904
C                                                                       00000914
      DO   370    I = 1,M                                               00000915
      IF(MSP .EQ. 0)  GO TO 345                                         00000916
      D(I)      =  0.                                                   00000917
      EK(I)     =  0.                                                   00000918
  345 IF(MT .EQ. 0)  GO TO 347                                          00000919
      ENT(I)   =  0.                                                    00000920
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
      EMT(I)  =  0.                                                     00000921
  347 DO   360   K = 1,NLAY                                             00000922
      IF(MSP .EQ. 0)  GO TO 348                                         00000923
      S9  =  EO(I,K) + EI(I,K)                                          00000924
      S12  =  1. - POIS(K) **2                                          00000930
  348 S17  =  THK(I,K) * DNAX(I,K)                                      00000932
      IF(MT .EQ. 0)  GO TO 349                                          00000937
      S16  =  ALFO(I,K) - ALFI(I,K)                                     00000938
      S10  =  EO(I,K) - EI(I,K)                                         00000939
      S13  =  1. - POIS(K)                                              00000940
      S18  =  EI(I,K) * ALFI(I,K)                                       00000942
      S11  =  TMP(I,K+1) - TMP(I,K)                                     00000944
  349 IF(MSP .EQ. 0)  GO TO 351                                         00000978
C                                                                       00000979
  350 D(I)  =  D(I) + THK(I,K) /S12 * S9                                00000980
C                                                                       00000984
      EK(I)  =  EK(I) + THK(I,K) /S12 *(THK(I,K)**2 *(3.*EO(I,K) +      00000985
     1 EI(I,K)) + S17 *(8.*EO(I,K) + 4.*EI(I,K)) + DNAX(I,K)**2 * 6.*S9)00000986
C                                                                       00000989
  351 IF(MT .EQ. 0)  GO TO 360                                          00000990
C                                                                       00000991
      S91  =  EO(I,K) * ALFO(I,K)                                       00000992
      S92  =  EI(I,K) * ALFI(I,K)                                       00000993
      S93  =  EI(I,K) * ALFO(I,K)                                       00000994
      S94  =  EO(I,K) * ALFI(I,K)                                       00000995
C                                                                       00000996
      ENT(I)  =  ENT(I) + THK(I,K) /S13 *(S91 *( TMP(I,K+1)*3.+TMP(I,K))00000997
     1 + S92 *(TMP(I,K)*3. + TMP(I,K+1)) + S93 *(TMP(I,K) + TMP(I,K+1)) 00000998
     2 + S94 *(TMP(I,K) + TMP(I,K+1)) )                                 00000999
C                                                                       00001004
      S101  =  S16 * S10 * S11                                          00001005
      S102  =  ALFI(I,K) * S10 * S11                                    00001006
      S103  =  EI(I,K) * S16 * S11                                      00001007
      S104  =  TMP(I,K) * S16 * S10 + S102 + S103                       00001008
      S105  =  S18 * S11                                                00001009
      S106  =  ALFI(I,K) * TMP(I,K) * S10                               00001010
      S107  =  TMP(I,K) * EI(I,K) * S16 + S105 + S106                   00001011
      S108  =  S18 * TMP(I,K)                                           00001012
C                                                                       00001014
      EMT(I)  =  EMT(I) + (THK(I,K) **2 *(S101 /5. + S104 /4. + S107 /3.00001015
     1 + S108 /2.) + S17 *(S101 /4. + S104 /3. + S107 /2. + S108))/S13  00001016
  360 CONTINUE                                                          00001020
      IF(MSP .EQ. 0)  GO TO 369                                         00001028
C                                                                       00001029
      D(I)  =  S5 * D(I)                                                00001030
      EK(I)  = S6 * EK(I)                                               00001032
```

Subr. to Set Up D, IK, ENT, EMT, EI, T, ALF (Section Properties) (Cont)

```
  369 IF(MT .EQ. 0)  GO TO 370                                              00001033
      EMT(I) = S8 * EMT(I)                                                  00001034
  370 ENT(I) = S7 * ENT(I)                                                  00001036
C                                                                           00001037
C                                              FORM STATION COLUMN          00001039
      DO   380   I = 1,N                                                    00001040
  380 X(I)  =  I                                                            00001042
      IF(MSP .EQ. 0)  GO TO 401                                             00001043
C                                         FIT VALUES TO ALL STATIONS        00001048
C                                                 MEMBRANE STIFFNESS        00001049
      CALL CODIMA (N,X,TX,  STA,D,M, 1.)                                    00001050
      DO   390   I = 1,N                                                    00001052
  390 D(I)  =  TX(I)                                                        00001054
C                                                                           00001058
C                                                 BENDING STIFFNESS         00001059
      CALL CODIMA (N,X,TX, STA,EK,M, 1.)                                    00001060
      DO   400   I = 1,N                                                    00001062
  400 EK(I)  =  TX(I)                                                       00001064
  401 IF(MT .EQ. 0)  GO TO 429                                              00001065
C                                                                           00001068
C                                                 TEMPERATURE LOAD          00001069
      CALL CODIMA (N,X,TX, STA,ENT,M, 1.)                                   00001070
      DO   410   I = 1,N                                                    00001072
  410 ENT(I)  =  TX(I)                                                      00001074
C                                                                           00001078
C                                                 TEMPERATURE MOMENT        00001079
      CALL CODIMA (N,X,TX, STA,EMT,M, 1.)                                   00001080
      DO   420   I = 1,N                                                    00001082
  420 EMT(I)  =  TX(I)                                                      00001084
  429 IF(PFLAG .LT. 0.) GO TO 430                                           00001086
      IF(SL2 .EQ. 0.)  GO TO 500                                            00001093
C                                         PRINT DATA ON NON-ZERO            00001999
      IF( PFLAG ) 430,500,430                                               00002000
  430 IF(MT .NE. 0)  GO TO 434                                              00002001
      DO  432    K = 1,NLAY                                                 00002002
      DO  432    I = 1,M                                                    00002003
  432 TMP(I,K)  =  0.                                                       00002004
  434 WRITE (6, 435)                                 EIFH, (TMPE1(I), YM1(I), 00002010
     1  TMPE2(I), YM2(I), TMPE3(I), YM3(I), I = 1,10),  (TMPA1(I),          00002011
     2  ALF1(I), TMPA2(I), ALF2(I), TMPA3(I), ALF3(I), I = 1,10)            00002012
  435 FORMAT(/// 7X,27HTHICKNESS INDICATOR        =,1PE13.4                 00002020
     2                ///34X, 40HCURVES OF TEMPERATURE VS. YOUNGS MODUL00002022
     3US // 8X,4HTEMP, 14X,3HYM1, 13X,4HTEMP, 14X,3HYM2, 13X,4HTEMP,        00002023
     4 14X,3HYM3/ 10(6E17.6/) //30X,49HCURVES OF TEMPERATURE VS. THERMAL00002024
     5 EXPANSION COEFF. // 8X,4HTEMP, 13X,4HALF1, 13X,4HTEMP, 13X,4HALF2,00002025
     6 13X,4HTEMP, 13X,4HALF3/ (6E17.6) )                                   00002026
C                                                                           00002029
      DO   439   K = 1,NLAY                                                 00002030
```

Subr. to Set Up D, IK, ENT, EMT, EI, T, ALF (Section Properties) (Cont

```
  439 WRITE  (6,440)  K, (STA(I), TMP(I,K), THK(I,K),  I = 1,M )           00002031
  440 FORMAT(/// 29X, 50HTABLE OF STATIONS VS. TEMP. AND THICKNESSES, LA00002040
     1YER, I2 // 39X,4HSTA., 11X,4HTEMP, 11X,4HTHK. / (32X, 1P3E15.5) ) 00002041
      IF(MT .EQ. 0)  GO TO 500                                          00002042
      WRITE (6,445)   (STA(I), TMP(I,NLAY1),  I = 1,M )                 00002043
  445 FORMAT(/// 36X, 35HSTATION VS. TEMPERATURE, OUTER FACE //46X,4HSTA00002044
     1., 11X, 4HTEMP /  (30X, 1P2E15.5) )                               00002045
C                                                                       00002049
C                                         COMPUTE AND SAVE DNA, ALF, E1, T 00002050
C                                          FOR BOTH STRESS SURFACES     00002051
C                                                                       00002052
  500 IF (STRI) 520,510,520                                             00002070
  510 WRITE (6,515)                                                     00002076
C                                                                       00002078
  515 FORMAT (1H-,9X,75HSECOND INTERFACE STRESS INDICATOR MISSING * * * 00002081
     1OUTER FACE HAS BEEN CHOSEN. )                                     00002082
C                                                                       00002084
      K  =  NLAY1                                                       00002086
      STRI  =  K - 1                                                    00002087
      GO TO 524                                                         00002088
  520 K = ABS(STRI) + 1.                                                00002090
  524 IF(MT .EQ. 0)  GO TO 530                                          00002091
  525 CALL CODIMA (N,X,ALF,STA,ALFO(1,K-1),M,1.)                        00002092
      CALL CODIMA (N,X,T2,STA,TMP(1,K),M, 1.)                           00002094
  530 CALL CODIMA (N,X,E2, STA,EO(1,K-1),M, 1.)                         00002096
      CALL CODIMA (N,X,DNA2,STA,DNAX(1,K),M, 1.)                        00002098
      POI2  =  POIS(K-1)                                                00002099
      IF(MT .NE. 0)  GO TO 536                                          00002100
      DO   535   I = 1,N                                                00002101
  535 T2(I)   =   0.                                                    00002102
      GO   TO   538                                                     00002104
C                                                                       00002109
  536 DO  537    L = 1,N                                                00002110
  537 T2(L)   =   T2(L) * ALF(L)                                        00002111
C                                                                       00002118
  538 IF(MT .EQ. 0)  GO TO 540                                          00002119
      CALL CODIMA (N,X,ALF, STA,ALFI,M, 1.)                             00002120
      CALL CODIMA (N,X,TX,STA,TMP,M, 1.)                                00002122
  540 CALL CODIMA (N,X,E1, STA,EI,M, 1.)                                00002124
      CALL CODIMA (N,X,DNA, STA,DNAX,M, 1.)                             00002126
C                                                                       00002129
      IF(MT .NE. 0)  GO TO 560                                          00002130
      DO  550    I = 1,N                                                00002131
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
      TX(I)  =  0.                                                      00002132
  550 ALF(I)  =  0.                                                     00002133
  560 IF(PFLAG .LT. 0.) GO TO 590                                       00002134
      IF(SL2 .EQ. 0.)  GO TO 599                                        00002135
C                                                                       00002139
  590 WRITE (6,591)   ELAY, ENMAT, POIS, EMAT,                          00002140
     1  (GSTA(I), GR(I,1), GR(I,2), GR(I,3), GR(I,4), GR(I,5), I=1,NOGR)00002141
C                                                                       00002149
  591 FORMAT(// 7X,27HNO. OF LAYERS       (ELAY)  =,1PE13.4// 7X,27HNO. OF00002150
     1 MATERIALS  (ENMAT) =, E13.4// 7X,27HPOISSONS RATIOS   (POIS)  =, 00002151
     2 3E20.4 / 34X, 3E20.4// 7X,27HMATERIAL IND.      (EMAT)  =, 3E20.4/00002152
     3 34X, 3E20.4/// 7X,15HGRADIENT TABLES // 9X,4HSTA., 33X,29HGRADIEN00002153
     4TS AT INNER INTERFACES  /                         (6E17.6)  )     00002154
  599 RETURN                                                            00002190
C                                                                       00002199
  600 WRITE ( 6,610)                                                    00003000
  610 FORMAT(/// 10X, 46HERROR IN DATLYR. EMAT VALUE LARGER THAN ENMAT.)00003010
      CALL  EXIT                                                        00003020
      STOP                                                              00003021
      END                                                               00010000
```

Subr. to Set Up D, IK, ENT, EMT, E1, T, ALF (Section Properties) (Cont)

```
$IBFTC STN
C     SUBROUTINE TO COMBINE THE TWO STATION COLUMNS FOR TEMP. AND
C     THICKNESS WHEN LAYERED VALUES ARE GIVEN AT DIFFERENT STATIONS.
C
      SUBROUTINE  STCOMB ( MT, MTH, M, A, B, STA )
C
      DIMENSION   A(20), B(20), STA(40)
C
      M  =  MT + MTH
      I  =  1
      J  =  1
      K  =  1
   10 S  =  A(J)
      F  =  B(K)
      IF(S - F) 20,30,40
   20 STA(I)  =  S
C
      J  =  J + 1
      IF(J - MT) 50,50,25
   25 IF (J .GT. 20) GO TO 50
      A(J)  =  1.E+10
      GO  TO  50
   30 STA(I)  =  S
C
      M  =  M - 1
      J  =  J + 1
      IF(J - MT) 35,35,33
   33 IF (J .GT. 20) GO TO 35
      A(J)  =  1.E+10
   35 K  =  K + 1
      IF(K - MTH) 50,50,37
   37 IF (K .GT. 20) GO TO 50
      B(K)  =  1.E+10
      GO  TO  50
C
   40 STA(I)  =  F
      GO  TO  35
C
   50 I  =  I + 1
      IF(I - M) 10,10,60
   60 RETURN
C
C     NOTE*  THIS WILL HANDLE THE CASE WHERE TSTA .NE. THSTA,  TSTA(MT)
```

Subroutine to Combine the Two Station Columns for Temp. and Thickness When Layered Values are Given at Different Stations

```
C              .NE. THSTA(MTH), BUT THF CURVE FIT CODIMA CANNOT EXTRA-     00000781
C              POLATE SO THEY ARE EQUAL AT THIS TIMF.                      00000782
      END                                                                     10000
```

Sub-outine to Combine the Two Station Columns for Temp, and Thickness When Layered Values are Given at Different Stations (Cont)

```
$IBFTC PXMAT                                                            00000001
C     SET UP P AND X MATRICES                          6J-148  ** LINK 5 00000010
C                                                                       00000019
      SUBROUTINE   PANDX                                                00000020
C                                                                       00000021
C                                                                       00000099
      DIMENSION  R(150), D(150), EK(150), ENT(150), EMT(150), PFE(150), 00000100
     1  PTH(150), PN(150), E1(150), T(150), ALF(150), DNA(150),          00000101
     2  RHOX(150), GAMA(150), WFE(150), WTHD(150), XSI(150),             00000102
     3  P0(4,4), P(4,4,150), X0(4), X(4,150), Z0(4), Z(4,150),           00000103
     4  EM1(4,4), EM2(4,4), EM3(4,4), EM4(4,4), EM5(4), EM6(4),          00000104
     5  EM1N(4,4), EM3N(4,4), EM5N(4), PSIP(4), PSIM(4),                 00000105
     6  A(4,4), B(4,4), C(4,4), E(4,4), F(4,4), GA(4,4), EC(4), G(4),    00000106
     7  A2(4,4), B2(4,4), C2(4,4), G2(4), CHI1(4,4),CHI2(4,4),CHI(4,4), 00000107
     8  XD(4,4), YD(4,4), ELD(4), DIS1(4,4), DIS2(4,4), DIS3(4),DIS4(4),00000108
     9  AI(4,4), BI(4,4), CI(4,4), GI(4), HI(4,4), EJI(4,4), FI(4),      00000109
     X RRNCH1(4,4), BRNCH2(4), BRNCH3(4), BFTA(4,4), ETA(4,4),          00000110
     1  AS1(4,4), BS1(4,4), CS1(4,4), GS1(4), ASN(4,4), BSN(4,4),        00000111
     2  CSN(4,4), GSN(4),A9(4,4),C9(4,4),F9(4)                          00000112
C                                                                       00000299
      EQUIVALENCE      (SDA(1),  EX  ),(SDA(2), GEOMI ),(SDA(3), SPRL ),00000300
     1(SDA(4),  UK   ),(SDA(5),  VK  ),(SDA(6),  WK   ),(SDA(7),  EMK ),00000301
     2(SDA(8),  PSI  ),(SDA(9),  ECX ),(SDA(10), BCIT ),(SDA(11), BCIB),00000302
     3(SDA(12), PFLAG),(SDA(13), STRI),(SDA(14),   EN ),(SDA(15), DEL ),00000303
     4(SDA(20), TLOC ),                                 (SDA(25), POI ),00000304
     1(SDA(26),  D   ),(SDA(176), EK ),(SDA(326), ENT ),(SDA(476), EMT),00000311
     2(SDA(626), PFE ),(SDA(776), PTH),(SDA(926), PN  ),(SDA(1076), E1),00000312
     3(SDA(1226), T  ),(SDA(1376),ALF),(SDA(1526), DNA),(SDA(2498),XSI),00000313
     4(SDA(1676),RHOX),(SDA(1826),GAMA),(SDA(1976), R),(SDA(2126),WTHD),00000314
     5(SDA(2276),WFE ),(SDA(2426),EM1),(SDA(2442), EM3),(SDA(2458),EM5),00000315
     6(SDA(2462),EM1N),(SDA(2478),EM3N),(SDA(2494),EM5N),(SDA(2649),E2),00000316
     7(SDA(2648),POI2),(SDA(2799), T2),(SDA(2949),DNA2),                00000317
     8(SDA(17), PSI0 ),(SDA(18),  PD ),(SDA(19),  EMD )                 00000318
C                                                                       00000339
      EQUIVALENCE      (DA(1),  EKK  ),(DA(2),   A0   ),(DA(3),  H0   ),00000340
     1(DA(4),    E0   ),(DA(5),  SIG0 ),(DA(6),  PIXI  ),(DA(7), PTHI  ),00000341
     2(DA(8),  SUM    ),(DA(9),  ENF0 ),(DA(10), ENFI  ),(DA(21), ENFOR),00000342
     3(DA(25), THETA )                                                  00000343
C                                                                       00000349
      COMMON     DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,     00000350
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                               00000351
      COMMON      SDA(3225), Z0,Z,    A2, B2, C2, G2,  A, B, C, G        00000360
C                                                                       00000399
```

Set Up P and X Matrices

```
      IF( PFLAG ) 1,3,3                                                 00000400
    1 WRITE(6, 2)                                                       00000401
    2 FORMAT(/// 10X, 19HENTERED PANDX, LNK5  )                          00000402
C                                                                       00000404
C      .                                      FIX SDA DATA TAPE NO. FOR READ  00000405
    3 S4   =  KTPW                                                      00000406
      KTPW   =  KTPR                                                    00000407
      KTPR   =  S4                                                      00000408
      LO   =  0                                                         00000409
      BRI   =   0.                                                      00000410
C                                                                       00000499
      DO   10     I = 1,4                                               00000500
      PSIP(I)   =   0.                                                  00000502
      PSIM(I)   =   0.                                                  00000504
      DO   10     J = 1,4                                               00000510
      BETA(I,J)   =  0.                                                 00000512
      FTA(I,J)   =  0.                                                  00000513
      CHI1(I,J)   =  0.                                                 00000514
      CHI(I,J)   =  0.                                                  00000515
      CHI2(I,J)   =  0.                                                 00000516
      DO 10  K = 1,150                                                  00000518
      X(I,K)   =  0.                                                    00000523
   10 P(I,J,K)   =  0.                                                  00000528
      BETA(1,1)   =  1.                                                 00000530
      BETA(2,2)   =  1.                                                 00000531
      BETA(3,3)   =  1.                                                 00000532
      ETA(4,4)   =  1.                                                  00000533
C                                                                       00000569
      DO  2000    ISEC = 1,KKE                                          00000570
C                                                                       00000598
C                                             READ  REGION DATA TAPE 12, 13 00000599
      READ    (KTPR)    (SDA(I), I = 1,3098)                            00000610
      N   =  EN                                                         00000690
      S1   =   1. - POI                                                 00000691
      S2   =   1. + POI                                                 00000692
C                                                                       00000960
C                                                                       00001099
      DEL2X   =   2. * DEL                                              00001100
      IBCT   =   BCIT                                                   00001120
      IBCB   =   BCIB                                                   00001130
   45 LSP   =   SPRL                                                    00001137
C                                                                       00001140
      DO    1000   I = 1,N                                              00001150
```

Set Up P and X Matrices (Cont)

```
      WTH  =  WTHD(I)                                                   00001160
      GAM  =  GAMA(I)                                                   00001170
      RHO  =  RHOX(I)                                                   00001180
      S4   =  ELAM2 * FK(I) * S1                                        00001190
      S6   =  3. * WFE(I) - WTH                                         00001200
      S7  =  3. * WTH - WFE(I)                                          00001210
      IF(I .NE. 1) GO TO 270                                            00001220
   50 IF(IBCT - 9) 90,180,90                                            00001230
C                                    TOP BND., OPEN AND DISCONTINUITY   00001390
   90 BP     =  (-D(3) + D(2)      + 3.* (D(2)  -  D))  /DEL2X          00001400
      WFEP   =  (-WFE(3) + WFE(2) + 3.* (WFE(2) - WFE))/DEL2X           00001410
      DP     =  (-EK(3) + EK(2)    + 3.* (EK(2) - EK))  /DEL2X          00001420
      TTP    =  (-ENT(3) + ENT(2) + 3.* (ENT(2) - ENT))/DEL2X           00001430
      EMTP   =  (-EMT(3) + EMT(2) + 3.* (EMT(2) - EMT))/DEL2X           00001440
C                                                                       00001447
  100 S9   =  ENF /RHO                                                  00001450
      S5   =  D(I) /2. * S9                                             00001460
      S8   =  S4 * S9 /8. * S6 * S7                                     00001470
      S15   =  S4 * S9 /2.                                              00001480
      S9   =  S9 **2                                                    00001490
      S10   =  S4 *(S2 * GAM**2 * WFE(I) + S9/2. * S6)                  00001500
      S11   =  S4 * S5 /D(I)                                            00001510
      S3   =  GAM * D(I)                                                00001520
C                                             ZERO BOUNDARY MATRICES    00001530
      DO  110    K = 1,4                                                00001540
      EM6(K)   =  0.                                                    00001550
      DO  110    L = 1,4                                                00001560
      EM2(K,L)   =  0.                                                  00001570
  110 EM4(K,L)   =  0.                                                  00001580
C                                                                       00001620
  140 EM2(1,1)   =  D(I) /DEL                                           00001630
      EM4(1,1)   =  POI * S3                                            00001640
      EM4(1,2)   =  POI * ENF / RHO    * D(I)                           00001650
      EM4(1,3)   =  D(I) * (WFE(I) + POI*WTH)                           00001660
      EM4(2,1)   = -S5 * S1 - S8                                        00001670
      EM2(2,2)   =  D(I)*S1/2. + S4/8. * S7**2                          00001680
      EM4(2,2)   =  -  GAM   * EM2(2,2)                                 00001690
      EM2(2,2)   =  EM2(2,2) /DEL                                       00001700
      S15   =  S4 * ENF /2. /RHO                                        00001710
      EM2(2,3)   =  S15 * S7                                            00001720
      EM4(2,3)   =  -  GAM   * EM2(2,3)                                 00001730
      EM2(2,3)   =  EM2(2,3) /DEL                                       00001740
      EM4(3,1)   =  - S10                                               00001750
```

Set Up P and X Matrices (Cont)

```
      EM2(3,2)  =  S11 * S7 /DEL                                        00001760
      EM4(3,2)  = -S11 *  GAM    * (S7 + 2.*S2*WTH)                     00001770
      EM2(3,3)  =  S4 * (2.*S9 + S2 * GAM **2) /DEL                     00001780
      EM4(3,3)  =  -S4 *(3. + POI) *  GAM * S9                          00001790
      EM2(3,4)  =  ELAM2 /DEL                                           00001800
      EM4(3,4)  =  ELAM2 * S1 * GAM                                     00001810
      EM2(4,3)  =  - 1. /DEL                                            00001820
      EM4(4,1)  =  WFF(I)                                               00001830
      EM6(1)  =  - ENT(I)                                               00001840
      EM6(3)  =  ELAM2 *  GAM   * S1 * EMT(I)                           00001850
      DO   150   K = 1,4                                                00001860
      DO   150   L = 1,4                                                00001862
  150 EM2(K,L)  =  0.5 * EM2(K,L)                                       00001864
      GO  TO  420                                                       00001866
C                                                                       00001919
  180 DO  185    K = 1,4                                                00001920
      EM6(K)  =  0.                                                     00001921
      DO  185    L = 1,4                                                00001922
      EM2(K,L)  =  0.                                                   00001923
  185 EM4(K,L)  =  0.                                                   00001924
C                            BOTTOM OR TOP BOUNDARY, CLOSED             00001929
      EM4(1,1)  =  1.                                                   00001930
      IF(ENF - 1.) 190, 210, 230                                        00001940
  190 EM2(4,4)  =  1. /DEL                                              00001950
  200 EM2(3,3)  =  1. /DEL                                              00001960
      EM4(2,2)  =  1.                                                   00001970
      GO  TO  260                                                       00001980
  210 EM4(1,1) = 0.                                                     00001985
      EM2(1,1) = 1. / DEL                                               00001990
      EM4(2,1) = 1.                                                     00001995
      EM4(2,2) = 1.                                                     00002000
      IF (GAM .LT. 0.)  EM4(2,2)  = -1.                                 00002005
  220 EM4(3,3)  =  1.                                                   00002010
      EM4(4,4)  =  1.                                                   00002020
      GO  TO  260                                                       00002030
  230 IF(ENF - 2.) 240, 240, 250                                        00002040
  240 EM4(4,3)  =  1.                                                   00002050
      GO  TO  200                                                       00002060
  250 EM4(2,2)  =  1.                                                   00002070
      GO  TO  220                                                       00002080
C                                                                       00002089
  260 IF(I .NE. 1) GO TO 800                                            00002090
C                                    TOP BOUNDARY, CLOSED               00002099
```

Set Up P and X Matrices (Cont)

```
      DO   265   K = 1,4                                                00002100
      G2(K)  =  0.                                                      00002105
      DO   265   L = 1,4                                                00002110
      A2(K,L)    =  2. * EM2(K,L)                                       00002115
      C2(K,L)    =  - .25 * A2(K,L)                                     00002120
  265 EM2(K,L)   =  1.5 * EM2(K,L)                                      00002125
      CALL MSU  (4,4, EM4,EM2,B2)                                       00002130
      GO  TO  1000                                                      00002140
C                                                                       00002169
  270 IF(I .NE. N)  GO TO 400                                           00002170
      IF(IBCB - 9)  290,180,290                                         00002180
C                                  BOTTOM BND.,  OPEN AND DISCONTINUITY 00002199
  290 BP     =  (D(N-2) - D(N-1)  + 3.*(D(N) - D(N-1)))     /DEL2X      00002200
      WFEP   =  (WFE(N-2)-WFE(N-1) + 3.*(WFE(N) - WFE(N-1)))/DEL2X      00002210
      DP     =  (EK(N-2) - EK(N-1) + 3.*(EK(N) - EK(N-1)))  /DEL2X      00002220
      TTP    =  (ENT(N-2)-ENT(N-1) + 3.*(ENT(N) - ENT(N-1)))/DEL2X      00002230
      EMTP   =  (EMT(N-2)-EMT(N-1) + 3.*(EMT(N) - EMT(N-1)))/DEL2X      00002240
      GO  TO  100                                                       00002250
C                                       BOTTOM DISCONTINUITY POINT, J(I) 00002289
  330 DPREV   =  DEL                                                    00002290
      WFEN   =  WFE(N)                                                  00002291
      IF(PD .NE. 0.)  GO TO 332                                         00002292
      IF(EMD .NE. 0.)  GO TO 332                                        00002294
      IF(ECX .NE. 0.)  GO TO 332                                        00002301
      IF(PSI .NE. 0.)  GO TO 332                                        00002302
      SKIP  =  1.                                                       00002303
  332 CALL INV  (4, A, PI, IERR)                                        00002306
       ECX   =  ECX/A0                                                  00002307
      CHI(2,2)  =  1.                                                   00002308
      CHI(4,4)  =  1.                                                   00002309
      CHI(1,1)   =  COSD( PSI )                                         00002310
      CHI(3,3)    =  CHI(1,1)                                           00002311
      CHI(3,1)    =  SIND( PSI )                                        00002312
      CHI(1,3)    = -CHI(3,1)                                           00002313
      IF(PD .EQ. 0.) GO TO 333                                          00002314
      PSIP(3)   =  - COSD( PSIO ) * PD / SQ6                            00002315
      PSIP(1)   =  SIND( PSIO ) * PD / SQ6                              00002316
  333 IF(EMD .EQ. 0.) GO TO 337                                         00002317
      PSIM(4)   =  - EMD / SQ4                                          00002318
C                                                                       00002319
  337 IF(IBCB .EQ. 10)  GO TO 350                                       00002320
      CHI2(1,4)   =  ECX * CHI(1,1)                                     00002330
      CHI2(3,4)   =  ECX * CHI(3,1)                                     00002331
```

Set Up P and X Matrices (Cont)

```
      CHI2(4,1) = -FCX/FLAM2                                             00002332
      CHI1(1,1)  =  CHI(1,1)                                             00002350
      CHI1(1,3)  =  CHI(1,3)                                             00002351
      CHI1(2,2)  =  1. + ECX * WTH                                       00002352
      CHI1(2,3)  =  ECX * ENF /RHO                                       00002353
      CHI1(3,1)  =  CHI(3,1)                                             00002354
      CHI1(3,3)  =  CHI(3,3)                                             00002355
      CHI1(4,4)  =  1.                                                   00002356
  338 CALL DOLP          ( EM2, EM4, EM6, AI, BI, CI, HI, EJI, GI, FI)   00002370
      GO  TO  1000                                                       00002400
C                                          BOTTOM BRANCH POINT           00002409
  350 IF(BRI .EQ. 1.)  GO TO 354                                         00002410
      CALL  DOO(BRNCH1, BRNCH2, BRNCH3)                                  00002412
      BRI  =  1.                                                         00002422
C                                                                        00002429
  354 CALL MMY  (4,4,4, A,C,E)                                           00002430
      CALL MMY  (4,4,4, EM2,E,F)                                         00002435
      CALL MAD  (4,4,  F,EM2,F)                                          00002440
      CALL MMY  (4,4,1, F,X(1,N-1),EC)                                   00002445
      CALL MMY  (4,4,1, A,G,GI)                                          00002450
      CALL MMY  (4,4,1, EM2,GI,FI)                                       00002455
      CALL MSU  (4,4,  FI,EC,    FI)                                     00002460
      CALL MMY  (4,4,4, E,P(1,1,I-1),F)                                  00002465
      CALL MMY  (4,4,4, A,B,E)                                           00002470
      CALL MSU  (4,4,  F,E,E)                                            00002475
      CALL MAD  (4,4,  E,P(1,1,I-1),E)                                   00002480
      CALL MMY  (4,4,4, EM2,E,    EJI)                                   00002485
      CALL MMY  (4,4,4, BETA,CHI,HI)                                     00002490
      CALL MAD  (4,4,  EJI,EM4,EJI)                                      00002495
      CALL MMY  (4,4,4, HI,EJI,CI)                                       00002500
      CALL MAD  (4,4,  CI,ETA,CI)                                        00002505
      CALL MMY  (4,4,4, ETA,EJI,BI)                                      00002510
      CALL MAD  (4,4,  BI,HI,BI)                                         00002515
      CALL INV  (4, BI, PI, IERR)                                        00002520
      CALL MMY  (4,4,4, CI,BI,    AI)                                    00002525
      CALL MAD  (4,4,  BRNCH1,AI,  BRNCH1)                               00002530
      CALL MMY  (4,4,1, CHI,EM6,EC)                                      00002535
      CALL MMY  (4,4,1, HI,FI,GI)                                        00002540
      CALL MAD  (4,1,  EC,GI,    EC)                                     00002545
      CALL MAD  (4,1,  BRNCH2,EC,BRNCH2)                                 00002550
      CALL MMY  (4,4,1, ETA,FI,GI)                                       00002555
      CALL MMY  (4,4,1, AI,GI,    EC)                                    00002560
      CALL MAD  (4,1,  BRNCH3,EC,BRNCH3)                                 00002565
```

Set Up P and X Matrices (Cont)

```
      GO TO 1000                                                       00002570
C                                                 GENERAL DERIVATIVES  00002880
  400 BP   =  (D(I+1) - D(I-1)) /DEL2X                                 00002890
      WFEP  =  (WFE(I+1) - WFE(I-1)) /DEL2X                            00002900
      DP  =  (EK(I+1) - EK(I-1)) /DEL2X                                00002910
      TTP  =  (ENT(I+1) - ENT(I-1)) /DEL2X                             00002920
      EMTP  =  (EMT(I+1) - EMT(I-1)) /DEL2X                            00002930
C                                                                      00002939
  410 S3   =  GAM * D(I)                                               00002940
      S5   =  D(I) /2. * ENF /RHO                                      00002950
      S8   =  S4 * ENF /8. /RHO * S6 * S7                              00002960
      S9   =  (ENF /RHO) **2                                           00002970
      S10 =  S4 * (S2 * GAM**2 * WFE(I) + S9/2. * S6)                  00002980
      S11 =  S4 * S5 /D(I)                                             00002990
  420 DO   430   K = 1,4                                               00003000
      DO   430   L = 1,4                                               00003010
  430 E(K,L)   =  0.                                                   00003020
      F(2,4)   =  0.                                                   00003030
      F(4,2)   =  0.                                                   00003031
      F(4,4)   =  0.                                                   00003032
      E(1,1)   =  D(I) /DEL                                            00003050
      F(1,1)   =  S3 + BP                                              00003060
      S12   =  WTH * WFE(I)                                            00003070
      GAM2   =     GAM **2                                             00003080
      GA(1,1)   =  POI * BP * GAM - D(I)*(POI*S12 + GAM2 + S1*S9 /2.)  00003090
     1  - S4 *(S2*GAM2*WFE(I)**2 + S6**2 *S9 /8.)                      00003100
      F(1,2)   =  S2 * S5 + S8                                         00003110
      GA(1,2)   =  POI*ENF/ RHO * BP - (3. - POI)*S5*GAM    - S11*2.   00003120
     1 * GAM   *(S6*S7/8. + S2*S12)                                    00003130
      F(1,3)   =  D(I)*(WFE(I) + POI*WTH) + S10                        00003140
      GA(1,3)   =  D(I)*(WFEP +   GAM *(WFE(I)-WTH))+ BP*(WFE(I) + POI* 00003150
     1 WTH) - S4*S9 * GAM  *(S6/2. + S2*WFE(I))                        00003160
      F(1,4)   =  FLAM2 * WFE(I)                                       00003170
      GA(1,4)   =  F(1,4) * S1 * GAM                                   00003180
      F(2,1)   =  - F(1,2)                                             00003190
      GA(2,1)   =  -S5*GAM *(3.-POI) - S1*ENF/2. * BP /RHO + S11 * 2.  00003200
     1 *( -S2 * GAM *S12 +   GAM /8. *(6.*S12 - 7.*WFE(I)**2 - 3.*WTH  00003210
     2 **2) - WFEP/4. *(5.*WTH - 3.*WFE(I)) ) - S11*DP/EK(I)/4.*S6*S7  00003220
      E(2,2)   = (D(I)/2.*S1 + S4/8. * S7**2) /DEL                     00003230
      F(2,2)   =  S1/2. *( GAM * D(I) + BP) - S4/8.*S7 *(2.*WFEP - GAM 00003240
     1 *(5.*WFE(I) - 3.*WTH)) + FLAM2/8.*DP*S1 *S7**2                  00003250
      GA(2,2)   =  - GAM * F(2,2) + D(I) *(S1/2.*S12 - S9) - S4 *(S2*S9 00003260
     1 *WTH**2 - S12/8. * S7**2)                                       00003270
```

Set Up P and X Matrices (Cont)

```
      E(2,3)  =  S11 * S7 /DEL                                          00003280
      F(2,3)  =  S11 *(2.*S2* GAM  *WTH - WFEP + 3.* GAM  * WFE(I) -    00003290
     1 WTH)) + S11/EK(I)*DP * S7                                        00003300
      GA(2,3)  =  - S5*2. *(WTH + POI*WFE(I)) + S4*S5 /D(I) *(GAM *     00003310
     1 WFEP - 2.*GAM2*WFE(I) - 2.*S2*S9*WTH + S7 *(GAM2 + S12)) - S11/  00003320
     2 EK(I)*DP *   GAM  * S7                                           00003330
      GA(2,4)  =  -POI * ELAM2 * WTH * ENF /RHO                         00003340
      F(3,1)  =  - F(1,3)                                               00003360
      S13  =  WTH + POI*WFE(I)                                          00003370
      GA(3,1)  =  -D(I)* GAM * S13 + ELAM2*EK(I)*S1 *( GAM * S2 *(GAM2  00003380
     1 *WFE(I) - GAM  * WFEP - WFE(I) *(S9 - 2.*S12)) + S9/2. *(GAM     00003390
     2 *(WFE(I) - WTH) - 3.*WFEP)) - ELAM2*DP*S1 *(S2*GAM2*WFE(I) + S9  00003400
     3 /2. * S6)                                                        00003410
      E(3,2)  =  E(2,3)                                                 00003420
      F(3,2)  =  S11 *( GAM   *( WFE(I)*3. -WTH*(5. + 2.*POI)) - WFEP)  00003430
     1 + S11*DP/EK(I) * S7                                              00003440
      GA(3,2)  =  -D(I)*ENF /RHO * S13 + S11 *(2.*S2 *(S12*WTH - GAM2 * 00003450
     1 (WFE(I) - 2.*WTH) - S9*WTH) +  GAM * WFEP + 3.*GAM2*(WTH - WFE(I)00003460
     2 ) + S12*S7) - S11*DP/EK(I) *( GAM   *(2.*S2*WTH + S7) ).         00003470
      E(3,3)  =  S4 *(2.*S9 + S2*GAM2) /DEL                             00003480
      F(3,3)  = -S4*(S2*GAM *(2.*S12 + GAM2) + 2.*GAM * S9) + ELAM2     00003490
     1 *DP*S1 *(S2*GAM2 + 2.*S9)                                        00003500
      GA(3,3)  =  -D(I) *(WFE(I)**2 + 2.*POI*S12+WTH**2)+S4*S9*(S2*(S12-00003510
     1 S9 + 2.*GAM2) + 2.*(GAM2 + S12)) - S1*S9*DP*ELAM2 *(3.+POI)*GAM  00003520
      E(3,4)  =  ELAM2 /DEL                                             00003530
      F(3,4)  =  ELAM2 * GAM *(2. - POI)                                00003540
      GA(3,4)  =  - ELAM2 * (S1*S12 + POI*S9)                           00003550
      F(4,1)  =  EK(I) * WFE(I)                                         00003560
      GA(4,1)  =  EK(I) *(WFEP + POI*GAM*WFE(I))                        00003570
      GA(4,2)  =  E (I) * POI*ENF*WTH /RHO                              000035
      E(4,3)  =  -EK(I) /DEL                                            00003590
      F(4,3)  =  -EK(I) * POI * GAM                                     00003610
      GA(4,3)  =  EK(I) * POI * S9                                      00003630
      GA(4,4)  =  - 1.                                                  00003640
      G (1)  =  (-PFE(I) + TTP - ELAM2 *S1*GAM*WFE(I)*EMT(I)) * DEL2X   00003650
      G (2)  =  (-PTH(I) - ENF/RHO*(ENT(I)+ ELAM2*S1*WTH*EMT(I) ))*DEL2X00003660
      G (3)  =  (-PW(I) - (WFE(I) + WTH)*ENT(I) - ELAM2*S1 *(GAM*EMTP   00003670
     1 - EMT(I) * (S12 - S9) )) * DEL2X                                 00003680
      G (4)  =  EMT(I) * DEL2X                                          00003690
C                                                                       00003700
      DO   450   K = 1,4                                                00003710
      DO   450   L = 1,4                                                00003720
  450 E(K,L)  =  2. * E(K,L)                                            00003730
```

Set Up P and X Matrices (Cont)

```
C                                                    TEST FOR SPRING       00003739
      IF(I .NE. LSP)  GO TO 510                                            00003740
      S3  =  A0 /E0 * A0 /HC                                               00003741
      GA(1,1)  =  GA(1,1) - UK * S3                                        00003742
      GA(2,2)  =  GA(2,2) - VK * S3                                        00003743
      GA(3,3)  =  GA(3,3) - WK * S3                                        00003744
      S3  =  S3 /A0 * EMK * WFE(I)                                         00003745
      F(1,3)  =  F(1,3) - S3                                               00003746
      GA(1,1)  =  GA(1,1) + S3 * WFE(I)                                    00003747
C                                                                          00003749
  510 CALL MAD  (4,4, E,F,A)                                               00003750
      CALL MSU  (4,4, E,F,C)                                               00003755
      DO  515     K = 1,4                                                  00003760
      DO  515     L = 1,4                                                  00003765
      E(K,L)  =  -2. * E(K,L)                                              00003770
  515 GA(K,L)  =  DEL2X * GA(K,L)                                          00003775
      CALL MAD  (4,4, E,GA,B)                                              00003780
C                                                                          00003784
      IF(I - 2) 520,590,600                                                00003785
C                             I  =  1 **PRESERVE  A, B, C, G MATRICES      00003786
  520 CALL DOA (AS1, BS1, CS1, GS1)                                        00003787
      IF(IBCT - 9) 820,1000,900                                            00003794
  590 IF(IBCT -10) 670,720,750                                             00003795
  600 IF(I .NE. N)  GO TO 720                                              00004000
C                             I  =  N **PRESERVE  A, B, C, G MATRICES      00004001
      CALL DOB (ASN, BSN, CSN, GSN)                                        00004002
      IF(IBCB - 9) 770,1000,330                                            00004010
C                          TOP BOUNDARY (2),  OPEN OR CLOSED               00004119
  670 CALL INV  (4, C, PI, IERR)                                           00004120
      CALL MMY  (4,4,4, B2,C,EM4)                                          00004130
      CALL MMY  (4,4,4, EM4,B,B2)                                          00004140
      CALL MSU  (4,4,  B2,A2,B2)                                           00004150
      CALL INV  (4, B2, PI, IERR)                                          00004160
      IF(IBCT - 9) 680,675,1000                                            00004162
  675 CALL MMY  (4,4,4, EM4,A,   )                                         00004164
      CALL MSU  (4,4,  A2,C2,A2)                                           00004166
      CALL MMY  (4,4,4, B2,A2,P(1,1,2))                                    00004168
      GO  TO  690                                                          00004170
  680 CALL MMY  (4,4,4, B2,FM4,A2)                                         00004175
      CALL MMY  (4,4,4, A2,A,P(1,1,2))                                     00004180
  690 CALL MMY  (4,4,1, EM4,G,EM6)                                         00004190
      CALL MSU  (4,1,  EM6,G2,G2)                                          00004200
      CALL MMY  (4,4,1, B2,G2,X(1,2))                                      00004210
```

Set Up P and X Matrices (Cont)

```
C                               I  =  2 **PRESERVE  A, B, C, G MATRICES     00004220
      CALL  DO1                                                             00004250
      GO  TO   1000                                                         00004290
C                                        GENERAL SOLUTION FOR P AND X       00004329
  720 CALL MMY   (4,4,4, C,P(1,1,I-1),EM4)                                  00004340
      CALL MSU  (4,4,  B,EM4,EM4)                                           00004350
      CALL INV  (4, EM4, PI, IERR)                                          00004360
      CALL MMY  (4,4,1, C,X(1,I-1),EM6)                                     00004370
      CALL MSU  (4,1,  G,EM6,EM6)                                           00004380
C                                                                           00004389
      IF(I .EQ. N)  GO TO 999                                               00004390
      CALL MMY  (4,4,4, EM4,A,P(1,1,I))                                     00004400
      CALL MMY  (4,4,1, EM4,EM6,X(1,I))                                     00004410
      GO  TO  1000                                                          00004490
C                                      POINT JUST BEYOND DISCONTINUITY      00004500
  750 CALL MMY  (4,4,4, DIS2,P(1,1,I-2),EM4)                                00004510
      CALL MMY  (4,4,4, C,DIS1,EM2)                                         00004512
      CALL MMY  (4,4,4, C,EM4,AI)                                           00004514
C                                                                           00004519
      CALL MMY  (4,4,1, DIS2,X(1,I-2),EM6)                                  00004520
      CALL MSU  (4,1,  EM6,DIS4,EM6)                                        00004522
      CALL MSU  (4,1,  EM6,DIS3,EM6)                                        00004524
      CALL MMY  (4,4,1, C,EM6,GI)                                           00004526
      CALL MAD  ( ,4,    AI,EM2,   C)                                       00004527
      CALL MAD  (A,1,  G,GI,     G)                                         00004528
      GO  TO  720                                                           00004550
C                                          BOTTOM BOUNDARY, OPEN            00004609
  770 IBCX  =  IBCB                                                         00004610
      GO  TO  850                                                           00004615
C                                                                           00004619
  780 CALL INV  (4, A, PI, IERR)                                            00004620
      CALL MMY  (4,4,4, EM1 ,EM2,GA)                                        00004622
      CALL MMY  (4,4,4, GA,A,EM2)                                           00004624
      CALL MMY  (4,4,4, EM1 ,FM4,A)                                         00004626
      CALL MAD  (4,4, EM3 ,A,A)                                             00004628
      CALL MMY  (4,4,4, EM2,B,E)                                            00004630
      CALL MSU  (4,4, A,E,B)                                                00004632
      CALL MMY  (4,4,4, EM2,C,E)                                            00004634
      CALL MAD  (4,4, GA,E,C)                                               00004636
      CALL MMY  (4,4,1, EM1 ,EM6,EC)                                        00004638
      CALL MSU  (4,1, EM5 ,FC,EC)                                           00004640
      CALL MMY  (4,4,1, EM2,G,E)                                            00004642
      CALL MSU  (4,1, EC,E,G)                                               00004644
```

Set Up P and X Matrices (Cont)

```
      CALL  DO2                                                     00004648
      GO  TO  720                                                   00004650
C                                           BOTTOM BOUNDARY, CLOSED 00004659
  800 CALL  DO3 (EM2)                                               00004660
      CALL MAD  (4,4, EM4,EM2,B)                                    00004680
      CALL MMY  (4,4,4, A,P(1,1,N-2),EM2)                           00004685
      CALL MSU  (4,4, EM2,C,EM2)                                    00004690
      CALL MMY  (4,4,4, EM2,P(1,1,N-1),EM4)                         00004695
      CALL MAD  (4,4, B,EM4,EM4)                                    00004700
      CALL INV  (4, EM4, PI,IERR)                                   00004705
      CALL MMY  (4,4,1, EM2,X(1,N-1),EM6)                           00004710
      CALL MAD  (4,1, G,EM6,G)                                      00004730
      CALL MMY  (4,4,1, A,X(1,N-2),EM6)                             00004735
      CALL MSU  (4,1, G,FM6,EM6)                                    00004740
      GO  TO  999                                                   00004745
C                                        TOP BOUNDARY,  OPEN APEX   00004800
  820 IBCX  =  IBCT                                                 00004840
      GO  TO  850                                                   00004850
  830 CALL MMY  (4,4,4, EM1,EM2,GA)                                 00004860
      CALL INV  (4, C, PI, IERR)                                    00004870
      CALL MMY  (4,4,4, GA,C,EM2)                                   00004880
      CALL MMY  (4,4,4, EM1,EM4,C)                                  00004900
      CALL MAD  (4,4, EM3,C,C)                                      00004910
      CALL MMY  (4,4,4, EM2,B,E)                                    00004920
      CALL MAD  (4,4,  C,E,B2)                                      00004940
      CALL MMY  (4,4,4, EM2,A,E)                                    00004950
      CALL MAD  (4,4,  GA,E,A2)                                     00004960
      CALL MMY  (4,4,1, EM1,EM6,EC)                                 00004970
      CALL MSU  (4,1,  EM5,EC,EC)                                   00004980
      CALL MMY  (4,4,1, EM2,G,E)                                    00004990
      CALL MAD  (4,1,  EC,E,G2)                                     00005000
      GO  TO  1000                                                  00005020
C                                     SET UP BOUNDARY CONDITIONS    00005030
  850 IF(IBCX .EQ. 6) GO TO 868                                     00005033
      DO  855    K = 1,4                                            00005034
      EM5(K)  =  0.                                                 00005035
      EM1(K,K)  =  0.                                               00005036
  855 EM3(K,K)  =  0.                                               00005037
  860 GO TO (861, 862, 863, 864, 865), IBCX                         00005040
C                                            FREE  BOUNDARY         00005059
  861 EM1(1,1)  =  1.                                               00005060
      EM1(2,2)  =  1.                                               00005061
      EM1(3,3)  =  1.                                               00005062
```

Set Up P and X Matrices (Cont)

```
      EM3(4,4)  =  1.                                                    00005063
      GO  TO  870                                                        00005064
C                                              ROLLER  BOUNDARY          00005079
  862 EM1(1,1)  =  1.                                                    00005080
      EM3(2,2)  =  1.                                                    00005081
      EM3(3,3)  =  1.                                                    00005082
      EM3(4,4)  =  1.                                                    00005083
      GO  TO  870                                                        00005084
C                                   FIXED OR CLAMPED  BOUNDARY           00005099
  863 EM1(4,4)  =  1.                                                    00005100
      EM3(1,1)  =  1.                                                    00005101
      EM3(2,2)  =  1.                                                    00005102
      EM3(3,3)  =  1.                                                    00005103
      GO  TO  870                                                        00005104
C                                   SIMPLY SUPPORTED (HINGED)            00005119
  864 EM3(1,1)  =  1.                                                    00005120
      EM3(2,2)  =  1.                                                    00005121
      EM3(3,3)  =  1.                                                    00005122
      EM3(4,4)  =  1.                                                    00005123
      GO  TO  870                                                        00005124
C                                              COMPLETE (CLOSED)         00005139
  865 EM1(3,3)  =  1.                                                    00005140
      EM1(4,4)  =  1.                                                    00005141
      EM3(1,1)  =  1.                                                    00005142
      EM3(2,2)  =  1.                                                    00005143
      GO TO  870                                                         00005144
C                                                                        00005149
  868 IF(I .NE. N)  GO TO 870                                            00005150
      CALL  DO4                                                          00005155
      GO  TO  890                                                        00005160
C                                            PRINT BOUNDARY MATRICES     00005169
  870 CALL  DO5                                                          00005170
C                                                                        00005279
  890 IF(I - 1) 780, 830, 780                                            00005280
C                                                                        00005299
  900 IF(IBCT .NE. 10)  GO TO 920                                        00005300
      SKIP = 0.                                                          00005305
C                                            TOP BRANCH POINT            00005309
      BRI  =  0.                                                         00005310
      CALL INV  (4, C, PI, IERR)                                         00005320
      CALL MMY  (4,4,4, EM2,C,E)                                         00005322
      CALL MMY  (4,4,4, E,A,GA)                                          00005324
      CALL MAD  (4,4,  EM2,GA,    GA)                                    00005326
```

Set Up P and X Matrices (Cont)

```
      CALL MMY  (4,4,1, E,G,    GI)                                     00005328
      CALL MMY  (4,4,4, E,B,    AI)                                     00005330
      CALL MAD  (4,4,  AI,EM4,AI)                                       00005332
      CALL MMY  (4,4,4, BETA,AI,CI)                                     00005334
      CALL MAD  (4,4,  CI,ETA,CI)                                       00005336
      CALL MMY  (4,4,4, ETA,AI,EJI)                                     00005338
      CALL MAD  (4,4,  EJI,BETA,AI)                                     00005340
      CALL MMY  (4,4,4, BRNCH1,AI,BI)                                   00005342
      CALL MSU  (4,4,  CI,BI,    BI)                                    00005344
      CALL INV  (4, BI, PI, IERR)                                       00005346
      CALL MMY  (4,4,4, ETA,GA,CI)                                      00005348
      CALL MMY  (4,4,4, BRNCH1,CI,A)                                    00005350
      CALL MMY  (4,4,4, BETA,GA,B)                                      00005352
      CALL MSU  (4,4,  B,A,B)                                           00005354
      CALL MMY  (4,4,4, BI,B,    P)                                     00005356
      CALL MSU  (4,1,  EM6,PSIP,EM6)                                    00005357
      CALL MMY  (4,4,1, ETA,GI,FI)                                      00005358
      CALL MSU  (4,1,  EM6,PSIM,EM6)                                    00005359
      CALL MMY  (4,4,1, BETA,GI,EC)                                     00005360
      CALL MSU  (4,1,  EC,EM6,EC)                                       00005362
      CALL MAD  (4,1,  EC,BRNCH2,EC)                                    00005364
      CALL MSU  (4,1,  EC,BRNCH3,EC)                                    00005366
      CALL MMY  (4,4,1, BRNCH1,FI,GI)                                   00005368
      CALL MSU  (4,1,  EC,GI,EC)                                        00005370
      CALL MMY  (4,4,1, BI,EC,    X)                                    00005372
      DO  903  K = 1,4                                                  00005385
      F9(K) =  FI(K)                                                    00005387
      DO  903  L = 1,4                                                  00005389
      A9(K,L) = AI(K,L)                                                 00005391
  903 C9(K,L) = CI(K,L)                                                 00005393
      GO TO 1000                                                        00005400
C                                        TOP DISCONTINUITY POINT, J(II) 00009299
  920 IF(SKIP .NE. 1.)  GO TO  930                                      00009300
      IF(DEL .NE. DPREV) GO TO 930                                      00009301
      SKIP  =  0.                                                       00009302
      IF(WFE .NE. WFEN) GO TO 930                                       00009303
      ALFA  = DEL /DPRFV                                                00009304
      ALFA2  =  ALFA **2                                                00009306
      S3  =  1. + ALFA                                                  00009308
      S4  = -ALFA /2.                                                   00009310
      S8  =  S3 /2.                                                     00009312
      DO   928   K = 1,4                                                00009330
      DO   927   L = 1,4                                                00009340
```

Set Up P and X Matrices (Cont)

```
      E(K,L)  =  E(K,L) * S4                                              00009344
      C(K,L)  =  C(K,L) * ALFA2                                           00009346
      A(K,L)  =  E(K,L) + F(K,L)                                          00009348
      B(K,L)  = (F(K,L) * ALFA + GA(K,L) /2. - A(K,L) ) * S3              00009350
      DIS1(K,L)  =  0.                                                    00009352
      DIS2(K,L)  =  0.                                                    00009354
      DIS3(K)  =  0.                                                      00009360
      DIS4(K)  =  0.                                                      00009362
      G(K)  =  G(K) * S8                                                  00009364
  428 DIS1(K,K)  =  1.                                                    00009370
      GO  TO  720                                                         00009380
C                                                                         00010099
  930 CALL MMY  (4,4,4, EM4,CHI2,E)                                       00010100
      CALL MMY  (4,4,1, EM4,PSIM,ELD)                                     00010101
      CALL MSU  (4,4,  E,CHI, E)                                          00010102
      CALL MSU  (4,1,  ELD,PSIP,PSIP)                                     00010103
      CALL MMY  (4,4,4, E,HI ,XD)                                         00010104
      CALL MMY  (4,4,1, E,FI,ELD)                                         00010106
      CALL MAD  (4,1,  ELD,EM6,ELD)                                       00010108
      CALL MAD  (4,1,  ELD,PSIP, ELD)                                     00010109
      CALL MMY  (4,4,4, CHI2,EJI,E)                                       00010110
      CALL MAD  (4,4,  CHI1,E, F)                                         00010112
      CALL MMY  (4,4,4, EM4,F,GA)                                         00010114
      CALL MMY  (4,4,4, CHI,EJI,F)                                        00010116
      CALL MSU  (4,4,  GA,F, YD)                                          00010118
      CALL MMY  (4,4,4, CHI2,HI,GA)                                       00010120
      CALL MMY  (4,4,4, AI,BI, E)                                         00010122
      CALL MMY  (4,4,4, GA,F,DIS1)                                        00010124
      CALL MSU  (4,4,  CHI1,DIS1,DIS1)                                    00010126
      CALL MAD  (4,4,  DIS1,E,DIS1)                                       00010128
      CALL MMY  (4,4,4, XD,F, E)                                          00010130
      CALL MSU  (4,4,  YD,E, YD)                                          00010132
      CALL INV  (4, C, PI, IERR)                                          00010134
      CALL MMY  (4,4,4, C,A, F)                                           00010136
      CALL MMY  (4,4,4, EM2,F, E)                                         00010138
      CALL MAD  (4,4,  EM2,E,   A)                                        00010140
      CALL MMY  (4,4,4, C,B, F)                                           00010142
      CALL MMY  (4,4,4, EM2,F, E)                                         00010144
      CALL MMY  (4,4,4, E,DIS1,F)                                         00010146
      CALL MMY  (4,4,1, AI,GI,EC)                                         00010148
      CALL MMY  (4,4,1, GA,EC,DIS3)                                       00010150
      CALL MMY  (4,4,1, CHI2,FI,DIS4)                                     00010152
      CALL MAD  (4,1,  DIS4,PSIM,DIS4)                                    00010153
```

Set Up P and X Matrices (Cont)

```
      CALL MMY  (4,4,1, XD,EC,GI)                                       00010154
      CALL MAD  (4,1,  DIS3,DIS4,EC)                                    00010156
      CALL MAD  (4,1,  GI,ELD, ELD)                                     00010158
      CALL MMY  (4,4,1, B,EC, GI)                                       00010160
      CALL MSU  (4,1,  G,GI, G)                                         00010162
      CALL MMY  (4,4,1, C,G, GI)                                        00010164
      CALL MMY  (4,4,1, EM2,GI,G)                                       00010166
      CALL MAD  (4,1,  G,ELD,   G)                                      00010168
      CALL MAD  (4,4,  F,YD,   B)                                       00010170
      CALL MMY  (4,4,4, AI,CI,C)                                        00010172
      CALL MMY  (4,4,4, XD,C,F)                                         00010174
      CALL MAD  (4,4,  F,XD, F)                                         00010176
      CALL MMY  (4,4,4, GA,C,XD)                                        00010178
      CALL MAD  (4,4,  GA,XD,DIS2)                                      00010180
      CALL MMY  (4,4,4, E,DIS2,C)                                       00010182
      CALL MAD  (4,4,  C,F, C)                                          00010184
      SKIP  =  0.                                                       00010185
      DO  950    K = 1,4                                                00010190
      DO  950    L = 1,4                                                00010193
  950 C(K,L)  =  -C(K,L)                                                00010196
      GO  TO   720                                                      00010440
  999 CALL MMY  (4,4,1, EM4,EM6, Z(1,N))                                00010800
 1000 CONTINUE                                                          00010810
C                                  SAVE P AND X MATRICES ON TAPE 3      00010829
      WRITE (3)  (((P(K,L,M), L=1,4), X(K,M), K=1,4), M=L0,N),          00010830
     1 ((DIS1(K,L), DIS2(K,L), A9(K,L), BI(K,L), C9(K,L), AS1(K,L),     00010831
     2  BS1(K,L), CS1(K,L), ASN(K,L), BSN(K,L), CSN(K,L), A2(K,L),      00010832
     3  B2(K,L), C2(K,L), L=1,4),                              G2(K),   00010833
     4  DIS3(K), DIS4(K), F9(K), GI(K), GS1(K), GSN(K), K=1,4)           00010834
      DO  1010    K = 1,4                                               00010840
      X0(K)  =  X(K,N-1)                                                00010841
      DO  1010    L = 1,4                                               00010842
 1010 P0(K,L)  =  P(K,L,N-1)                                            00010843
 2000 CONTINUE                                                          00010847
      WRITE  (3)    S1                                                  00010850
      READ (KTPR) S1                                                    00010860
      IF( PFLAG ) 2005,2010,2010                                        00010870
 2005 WRITE(6, 2006)                                                    00010871
 2006 FORMAT(/// 10X, 19HLEAVING PANDX, LNK5  )                         00010872
 2010 RETURN                                                            00011000
      END                                                               00011010
```

Set Up P and X Matrices (Cont)

```
$IBFTC PXDO                                                                     1
C     DO LOOP SUBROUTINE                                  6J-148 ** LNK5   00000002
C                                                                                 8
C                                                                                 9
C     SUBROUTINE TO HELP PANDX FIT COMPILATION TABLE SIZE. VARIABLES,   00000010
C       STATEMENT NOS. AND IDENTS ARE COMPATIBLE WITH PANDX              00000011
C                                                                                19
      SUBROUTINE  DOLP            ( EM2, EM4, EM6, AI, BI, CI, HI, EJI,  00000020
     1                  GI, FI)                                                  21
C                                                                                99
      DIMENSION  A(4,4), B(4,4), C(4,4), G(4), A2(4,4), B2(4,4),        00000100
     1  C2(4,4), G2(4), EM1(4,4), EM3(4,4), EM5(4), EM1N(4,4),          00000101
     2  EM3N(4,4), EM5N(4), EM2(4,4), EM4(4,4), EM6(4), AI(4,4),        00000102
     3  BI(4,4), CI(4,4), HI(4,4), EJI(4,4), GI(4), FI(4)               00000103
C                                                                               309
      EQUIVALENCE                                                               313
     5(SDA(2276),WFE ),(SDA(2426),EM1),(SDA(2442), EM3),(SDA(2458),EM5),00000315
     6(SDA(2462),EM1N),(SDA(2478),EM3N),(SDA(2494),EM5N),(SDA(2649),E2) 00000316
C                                                                               349
      COMMON    DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,     00000350
     1  KKE, SQ3, SQ4, SQ6. ENF, IFR, KLM                               00000351
      COMMON     SDA(3225), ZO(604), A2, B2, C2, G2,  A, B, C, G        00000360
C                                                                              2368
C                                       SAVE BOTTOM DISCONT. MATRICES   00002369
  338 DO   340   K = 1,4                                                       2370
      GI(K)  =  G(K)                                                           2374
      FI(K)  =  EM6(K)                                                         2376
      DO   340   L = 1,4                                                       2380
      AI(K,L)  =  A(K,L)                                                       2384
      BI(K,L)  =  B(K,L)                                                       2386
      CI(K,L)  =  C(K,L)                                                       2387
      HI (K,L)  =  EM2(K,L)                                                    2390
  340 EJI(K,L)  = EM4(K,L)                                                     2392
      GO  TO  710                                                              2400
C                                                                              2404
      ENTRY  DOO(BRNCH1, BRNCH2, BRNCH3)                                00002405
      DIMENSION  BRNCH1(4,4), BRNCH2(4), BRNCH3(4)                      00002406
C                                           BOTTOM BRANCH POINT         00002409
      DO  352    K = 1,4                                                       2412
      BRNCH2(K)  =  0.                                                         2414
      BRNCH3(K)  =  0.                                                         2416
      DO  352    L = 1,4                                                       2418
  352 BRNCH1(K,L)  =  0.                                                       2420
```

DO Loop Subroutine

```
      GO  TO  710                                                     2422
C                                                                     3780
      ENTRY  DOA (AS1, BS1, CS1, GS1)                             0 003781
      DIMENSION  AS1(4,4), BS1(4,4), CS1(4,4), GS1(4)             00003782
C                            I  =  1 **PRESERVE  A, B, C, G MATRICES  00003786
  520 DO  522    K = 1,4                                              3787
      GS1(K)  =  G(K)                                                 3788
      DO  522    L = 1,4                                              3789
      AS1(K,L)  =  A(K,L)                                             3790
      BS1(K,L)  =  B(K,L)                                             3791
  522 CS1(K,L)  =  C(K,L)                                             3792
      CALL INV  (4, CS1, PI, IERR)                                0 0 3793
      GO  TO  710                                                     3794
C                                                                     3989
      ENTRY  DOB (ASN, BSN, CSN, GSN)                             0 003990
      DIMENSION   ASN(4,4), BSN(4,4), CSN(4,4), GSN(4)            00003992
C                            I  =  N **PRESERVE  A, B, C, G MATRICES  00004001
      DO  610    K = 1,4                                              4002
      GSN(K)  =  G(K)                                                 4003
      DO  610    L = 1,4                                              4004
      ASN(K,L)  =  A(K,L)                                             4005
      BSN(K,L)  =  B(K,L)                                             4006
  610 CSN(K,L)  =  C(K,L)                                             4007
      CALL INV  (4, ASN, PI, IERR)                                    4008
      GO  TO  710                                                     4009
C                                                                     4209
      ENTRY  DO1                                                      4210
C                            I  =  2 **PRESERVE  A, B, C, G MATRICES  00004220
      DO  700    K = 1,4                                              4230
      G2(K)  =  G(K)                                                  4240
      DO  700    L = 1,4                                              4250
      A2(K,L)  =  A(K,L)                                              4260
      B2(K,L)  =  B(K,L)                                              4270
  700 C2(K,L)  =  C(K,L)                                              4280
  710 RETURN                                                          4290
C                                                                     4629
      ENTRY  DO2                                                      4630
C                                        BOTTOM BOUNDARY, OPEN    00004639
      DO  785    K = 1,4                                              4646
      DO  785    L = 1,4                                              4647
  785 C(K,L)  =  - C(K,L)                                             4648
      GO TO  710                                                      4650
C                                                                     4654
```

DO Loop Subroutine (Cont)

```
      ENTRY  DO3 (EM2)                                                  4655
C                                           BOTTOM BOUNDARY, CLOSED  00004659
  8 0 DO  805     K = 1,4                                               4660
      G(K)  =  0.                                                       4662
      DO  805     L = 1,4                                               4664
      A(K,L)    =  .5 * EM2(K,L)                                        4666
      C(K,L)    =  -2. * EM2(K,L)                                   0 0 4668
  805 EM2(K,L)  =  1.5 * EM2(K,L)                                   0 0 4670
      GO TO  710                                                        4680
C                                                                       5139
      ENTRY  DO4                                                        5140
C                                            BOTTOM BNDRY. MATRICES 00005149
      DO  869     K = 1,4                                               5151
      EM5(K)   =  EM5N(K)                                               5152
      DO  869     L = 1,4                                               5153
      EM1(K,L)   =  EM1N(K,L)                                           5154
  869 EM3(K,L)   =  EM3N(K,L)                                           5155
C                                                                       5156
      ENTRY  DO5                                                      . 5158
C                                        PRINT BOUNDARY MATRICES     00005159
  870 WRITE (6, 880)  ((EM1(K,L), L=1,4),K=1,4), ((EM3(K,L), L=1,4),    00005160
     1  K=1,4), (EM5(K), K=1,4)                                         5161
  880 FORMAT(///10X, 21HBOUNDARY MATRICES *** //10X,11HEM1 (OMEGA) /    00005170
     1 4(1P4E20.7/)//10X,12HEM3 (LAMBDA) / 4(4E20.7/)//10X, 7HEM5 (L) / 00005171
     2   4E20.7 )                                                       5172
      GO  TO  710                                                       5179
C                                                                       5999
      END                                                               6000
```

DO Loop Subroutine (Cont)

```
$IBFTC INLDS                                                                          1
C     DEFLECTIONS AND INTERNAL LOADS                      6J-148   ** LINK 6   00000010
C                                                                                    11
      SUBROUTINE  INTLD                                                              12
C                                                                                    13
C                                                                                   199
      DIMENSION   FETH(150), RHOX(150), WTHD(150), WFE(150), ENT(150),  00000200
     1  GAMA(150), D(150), FK(150), FMT(150), DNA(150), F1(150), T(150),00000201
     2  ALF(150), XSI(150), EZ(150), T2(150), DNA2(150), R(150),        00000202
     3  P0(4,4), P(4,4,150), Y0(4), X(4,150), Z0(4), Z(4,150),          00000203
     4  DIS1(4,4), DIS2(4,4), DIS3(4), DIS4(4), BOT4(4), BQ(4,4), GQ(4),00000204
     6  EM4(4,4), EM6(4), A2(4,4), B2(4,4), C2(4,4), G2(4), FC(4), G(4),00000206
     7  AI(4,4), PI(4,4), CI(4,4), FI(4), GI(4), BRCH1(4,4), BRCH2(4,4),00000207
     8  BRCH3(4), BRCH4(4), BRCH5(4),                                   0 0  208
     X  AS1(4,4), BS1(4,4), CS1(4,4), GS1(4), ASN(4,4), BSN(4,4),       00000210
     1  CSN(4,4), GSN(4), Z1M1(4), ZNP1(4)                              00000211
C                                                                                   299
      EQUIVALENCE      (SDA(1),  EX  ),(SDA(2), GEOMI ),(SDA(3), SPRL ),00000300
     1(SDA(4),  UK    ),(SDA(5),  VK  ),(SDA(6),  WK   ),(SDA(7),  EMK ),00000301
     2(SDA(8),  PSI   ),(SDA(9),  ECX ),(SDA(10), BCIT ),(SDA(11), BCIB),00000302
     3(SDA(12), PFLAG),(SDA(13), STRI),(SDA(14),   EN ),(SDA(15), DFL ),00000303
     4(SDA(20), TLOC ),                              (SDA(25), POI ),00000304
     1(SDA(26),  D    ),(SDA(176), EK ),(SDA(326), ENT ),(SDA(476), EMT),00000311
     2(SDA(626), PFE ),(SDA(776), PTH),(SDA(926), PN   ),(SDA(1076), E1),00000312
     3(SDA(1226), T   ),(SDA(1376),ALF),(SDA(1526), DNA),(SDA(2498),XSI),00000313
     4(SDA(1676),RHOX),(SDA(1826),GAMA),(SDA(1976), R),(SDA(2126),WTHD),00000314
     5(SDA(2276),WFF ),(SDA(2426),EM1),(SDA(2442), EM3),(SDA(2458),EM5),00000315
     6(SDA(2462),FM1N),(SDA(2478),EM3N),(SDA(2494),EM5N),(SDA(2649),F2),00000316
     7(SDA(2648),POI2),(SDA(2799), T2),(SDA(2949),DNA2)                 00000317
C                                                                                   339
      EQUIVALENCE      (DA(1),  EKK  ),(DA(2),  A0   ),(DA(3),  H0    ),00000340
     1(DA(4),    E0   ),(DA(5),  C GO ),(DA(6),  PIXI  ),(DA(7), PTHI  ),00000341
     2(DA(8),   SUM   ),(DA(9),  ENFO ),(DA(10), ENFI  ),(DA(21), ENFOR),00000342
     3(DA(25), THETA )                                                  343
C                                                                                   349
      COMMON    DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,     00000350
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                               0.00.351
      COMMON      SDA(3225), Z0,Z,     A2, BQ, C2, GQ                   00000355
      DIMENSION USUM(150),VSUM(150),WSUM(150), EMFE(150), EMTH(150),    00000360
     1  EMFT(150), ENFE(150), ENTH(150), ENFT(150), SIGFE(150),         00000361
     2  SIGTH( 50), SIGFT(150), QFE(150), QTH(150), SGFE2(150),         00000362
     3  SGTH2(150), SGFT2(150)                                          363
C                                                                                   379
```

Deflections and Internal Loads

```
      LB = 0                                                            00000389
      IF( PFLAG ) 1,3,3                                                 00000390
    1 WRITE (6,2)                                                       00000391
    2 FORMAT(/// 10X, 19HENTERED INTLD, LNK6  )                         00000392
C                                                                       00000399
    3 DO  2000   KK = 1,KKE                                             00000400
      LX = 2                                                            00000410
      BACKSPACE  3                                                      00000480
      BACKSPACE  3                                                      00000485
      BACKSPACE   KTPR                                                  00000490
      BACKSPACE   KTPR                                                  00000491
C                                                                       00000498
C                                          READ DATA - P,X TAPE  /LNK5  00000499
      READ   (KTPR)    (SDA(I), I = 1,3098)                             00000500
      N  =  EN                                                          00000510
      IBCT  =  BCIT                                                     00000511
      IBCB  =  BCIB                                                     00000512
      S1   =   1. - POI                                                 00000513
      S2   =   1. + POI                                                 00000514
C                                                                       00000519
      READ  ( )  (((P(K,L,M), L=1,4), X(K,M), K=1,4), M=LO,N),          00000520
     1 ((DIS1(K,L), DIS2(K,L), AI(K,L), BI(K,L), CI(K,L), AS1(K,L),     00000521
     2   BS1(K,L), CS1(K,L), ASN(K,L), BSN(K,L), CSN(K,L), A2(K,L),     00000522
     3   BQ(K,L), C2(K,L), L=1,4),                          GQ(K),      00000523
     4   DIS3(K), DIS4(K), EI(K), GI(K), GS1(K), GSN(K), K=1,4)         00000524
C                                                                       00000698
      IF(IB 3 - 10) 305,290,300                                         00000700
  290 CALL MMY  (4,4,4, BI,BRCH1,B2)                                    00000702
      CALL MMY  (4,4,4, BI,BRCH2,EM4)                                   00000704
      CALL MAD  (4,1,   BRCH3,GI,EM6)                                   00000706
      CALL MMY  (4,4,1, BI, EM6 ,GI)                                    00000708
      CALL MMY (4,4,1,  B2 ,BRCH4,EM6)                                  00000710
      CALL MSU  (4,1,   EM6 ,GI,Z(1,N))                                 00000712
      CALL MMY  (4,4,1,  EM4,BRCH ,EM6)                                 00000714
      CALL MAD  (4,1,  Z(1,N), EM6 ,Z(1,N))                             00000716
      GO  TO  305                                                       00000720
C                                                                       00003998
C                                                                       0 )04008
C                           SET Z AT J- DISCONT. PT. SAVED FROM PREV. SEC.0. 04009
  300 DO   301     K = 1,4                                              00004010
  301 Z(K,N)  =  BOT4(K)                                                00  4011
C                                                                       00  4018
C                  COMPUTE   PER REGION,  FROM N THRU J-1 STORED IN Z( ) 00004019
```

Deflections and Internal Loads (Cont)

7

```
  305 DO   310   I = 1,N                                                          00004020
      IZ  =  N - I                                                                00004021
      CALL MMY  (4,4,1, P(1,1,IZ), Z(1,IZ+1),EM6)                                 00004022
  310 CALL MSU  (4,1,  X(1,IZ),EM6,Z(1,IZ))                                       00004023
C                                                                                 00004028
C                                 SAVE MATRICES FOR Z(N) IN BRANCHING             00004029
      IF(IBCT .NE. 10)  GO TO 360                                                 00004030
      DO   350   K = 1,4                                                          00004031
      BRCH3(K)  =  FI(K)                                                          00004032
      BRCH4(K)  =  Z(K,1)                                                         00004033
      BRCH5(K)  =  Z(K,2)                                                         00004034
      DO   350   L = 1,4                                                          00004035
      BRCH1(K,L)  =  AI(K,L)                                                      00004036
  350 BRCH2(K,L)  =  CI(K,L)                                                      00004037
      GO  TO  490                                                                 00004038
  360 IF(KKF .EQ. KK) GO TO 400                                                   00004040
C                                                                                 00004049
C                                           FORM Z AT J+ DISCONTINUITY            00004089
      CALL MAD  (4,1,  DIS3,DIS4,EM6)                                             00004090
      CALL MMY  (4,4,1, DIS2,Z0,DIS3)                                             00004091
      CALL MSU  (4,1,  EM6,DIS3,EM6)                                              00004092
      CALL MMY  (4,4,1, DIS1,Z,DIS3)                                              00004093
      CALL MAD  (4,1,  EM6,DIS3,EM6)                                              00004094
C                                           MOVE J- AND J+ Z VALUES               00004099
      DO   375   K = 1,4                                                          00004100
      BOT4(K)  =  Z(K,1)                                                          00004101
  375 Z(K,1)  =  EM6(K)                                                           00004102
C                                           TEST FOR FIRST SECTION                00004119
  400  IF(IBCT - 9)  410,408,490                                                  00004120
  408  IF(ENF.NE .0.)  GO TO 410                                                  00004121
      Z(1,1)  =  0.0                                                              00004122
      Z(2,1)  =  0.0                                                              00004123
      Z(4,1)  =(4.*Z(4,2)  -  Z(4,3))/ 3.0                                        00004125
      Z(3,1)  =(4.*Z(3,2)  -  Z(3,3))/ 3.0                                        00004124
      GO TO 490                                                                   00004128
C                                          (OPEN OR CLOSED TOP) Z AT 1            00004129
  410 CALL MMY  (4,4,1, BQ,Z(1,2),EM6)                                            00004130
      CALL MSU  (4,1,  GQ,EM6,G2)                                                 00004131
      CALL MMY  (4,4,1, A2,Z(1,3),EM6)                                            00004132
      CALL MSU  (4,1,  G2,EM6,G2)                                                 00004133
      CALL MMY  (4,4,1, C2,G2,Z(1,1))                                             00004134
C                                                                                 00004159
C                                 COMPUTE Z AT FICTITIOUS POINTS, 0 AND N+1       00004169
```

Deflections and Internal Loads (Cont)

```
 490 CALL MMY  (4,4,1, AS1,Z(1,2),EM6)                               00004170
     CALL MSU  (4,1,  GS1,FM6,GS1)                                   00004172
     CALL MMY  (4,4,1, BS1,Z(1,1),EM6)                               00004174
     CALL MSU  (4,1,  GS1,FM6,GS1)                                   00004176
     CALL MMY  (4,4,1, CS1,GS1,Z1M1)                                 00004178
C                                                                    00004179
     CALL MMY  (4,4,1, BSN,Z(1,N),EM6)                               00004180
     CALL MSU  (4,1,  GSN,EM6,GSN)                                   00004182
     CALL MMY  (4,4,1, CSN,Z(1,N-1),EM6)                             00004184
     CALL MSU  (4,1,  GSN,FM6,GSN)                                   00004186
     CALL MMY  (4,4,1, ASN,GSN,ZNP1)                                 00004188
C                                                                    00005299
C                                        COMPUTE INTERNAL LOADS      00005300
C                                                                    00005309
     S3   =  1. - POI **2                                            00005310
     S4   =  S1 /2.                                                  00005320
     S12  =  SIGO /EO /S3                                            00005330
     S5   =  ENF * THETA                                             00005390
     S20  =  (HO /AO) **2                                            00005400
     DEL2X =  2. * DEL                                               00005420
     IXL  =  0                                                       00005445
     L1   =  1                                                       00005450
     IF(IBCT .NE. 9)  GO TO  497                                     00005460
     L1   =  2                                                       00005470
     WP   =  (-Z(3,3) + Z(3,2) + 3. *(Z(3,2) - Z(3,1)))  /DEL2X      00005471
     FETH(1)  =  ENF * WP + WTHD * Z(2,1)                            00005472
 497 DO  498     I =L1,N                                             00005480
 498 FETH(I)  =  ENF /RHOX(I) * Z(3,I) + WTHD(I) * Z(2,I)            00005481
     IF (IBCB .NE. 9) GO TO 499                                      00005483
     WP = (Z(3,N-2) - Z(3,N-1) - 3.*(Z(3,N-1)-Z(3,N)))  /DEL2X       00005485
     FETH(N) = ENF * WP + WTHD(N) * Z(2,N)                           00005487
C                                                                    00005489
 499 DO  1000    I = 1,N                                             00005490
 500 IF(I .NE. 1) GO TO 520                                          00005495
     FETHP  =  (-FETH(3) + FETH(2) + 3. *(FETH(2) - FETH)) /DEL2X    00005496
     IF(IBCT .EQ. 9)  GO TO 507                                      00005497
C                                                                    00005498
C              I=1     DISCONTINUITY(JII) AND TOP BOUNDARY, OPEN     00005499
     UP   =  (Z(1,2) - Z1M1) /DEL2X                                  00005500
     VP   =  (Z(2,2) - Z1M1(2)) /DEL2X                               00005501
     WP   =  (Z(3,2) - Z1M1(3)) /DEL2X                               00005502
     EM6(4)  =  (Z(4,2) - Z1M1(4)) /DEL2X                            00005503
     ROP  =  (-RHOX(3) + RHOX(2) + 3. *(RHOX(2) - RHOX))  /DEL2X     00005504
```

Deflections and Internal Loads (Cont)

```
      GO  TO  515                                                       00005505
C                                                                       00005508
C                                       TOP BOUNDARY, CLOSED APEX, I=1  00005509
  507 UP  =  (-Z(1,3) + Z(I,2) + 3. *(Z(1,2) - Z(1,1)))  /DEL2X         00005510
      VP  =  (-Z(2,3) + Z(2,2) + 3. *(Z(2,2) - Z(2,1)))  /DEL2X         00005511
      WP  =  (-Z(3,3) + Z(3,2) + 3. *(Z(3,2) - Z(3,1)))  /DEL2X         00005512
      EM6(4)  =  (-Z(4,3) + Z(4,2) + 3. *(Z(4,2) - Z(4,1)))  /DEL2X     00005513
      IF(IXL .NE. 0)  GO TO 549                                         00005514
C                                            CLOSED BOUNDARY EQUATIONS  00005515
  508 IF(ENF - 2.) 511,509,510                                          00005516
  509 VP  =  -UP                                                        00005517
      GO  TO  512                                                       00005518
  510 UP  =  0.                                                         00005519
  511 VP  =  0.                                                         00005520
  512 ENFE(I)  =  D(I) *(S2 *(UP + WFE(I)*Z(3,I)) + ENF*POI*VP) - ENT(I)00005521
      S6  =  2. - ENF **2                                               00005522
      ENTH(I)  =  2. * ENFE(I) /S6                                      00005523
      ENFT(I)  =  ENF * ENFE(I) /S6                                     00005524
      EMFT(I)  =  ENF * Z(4,I) /S6                                      00005525
      EMTH(I)  =  2. * Z(4,I) /S6                                       00005526
      GO  TO  548                                                       00005527
C                                                                       00005679
  515 EM6(2)  =  VP                                                     00005680
      EM6(3)  =  WP                                                     00005690
      EM6(1)  =  UP                                                     00005700
      IF( IXL ) 549,545,549                                             00005710
  520 IF(I .NE. N) GO TO 540                                            00005720
      FETHP =  (FETH(N-2) - FETH(N-1) - 3.*(FETH(N-1)-FETH(N))) /DEL2X  00005722
      IF(IBCB .EQ. 9)  GO TO 526                                        00005723
C                                                                       00005728
C             I=N     DISCONTINUITY (JI) AND BOTTOM BOUNDARY, OPEN      00005729
      UP  =  (ZNP1(1) - Z(1,N-1)) /DEL2X                                00005730
      VP  =  (ZNP1(2) - Z(2,N-1)) /DEL2X                                00005731
      WP  =  (ZNP1(3) - Z(3,N-1)) /DEL2X                                00005732
      EM6(4)  =  (ZNP1(4) - Z(4,N-1)) /DEL2X                            00005733
      ROP  =  (RHOX(N-2)-RHOX(N-1) - 3.*(RHOX(N-1)-RHOX(N)))  /DEL2X    00005734
      GO  TO  515                                                       00005735
C                                                                       00005857
C                                           BOTTOM BOUNDARY, CLOSED     00005858
  526 UP = (Z(1,N-2)-Z(1,N-1) - 3.*(Z(1,N-1)-Z(1,N))) /DEL2X            00005860
      VP = (Z(2,N-2)-Z(2,N-1) - 3.*(Z(2,N-1)-Z(2,N)))  /DEL2X           00005861
      WP = (Z(3,N-2) - Z(3,N-1) - 3.*(Z(3,N-1)-Z(3,N)))  /DEL2X         00005862
      EM6(4) = (Z(4,N-2) - Z(4,N-1) - 3.*(Z(4,N-1)-Z(4,N)))/DEL2X       00005863
```

Deflections and Internal Loads (Cont)

```
      IF(IXL .NF. 0)  GO TO 549                                                 00005918
  527 GO  TO  508                                                               00005920
C                                                                               00006829
C                                                 GENERAL DERIVATIVES           00006830
  540 WP  =  (Z(3,I+1) - Z(3,I-1)) /DEL2X                                       00006840
      FETHP  = (FETH(I+1) - FETH(I-1)) /DEL2X                                   00006850
      ROP  =  (RHOX(I+1) - RHOX(I-1))  /DEL2X                                   00006860
      VP  =  (Z(2,I+1) - Z(2,I-1))  /DEL2X                                      00006870
      UP  =  (Z(1,I+1) - Z(1,I-1))  /DEL2X                                      00006880
      EM6(4)  =  (Z(4,I+1) - Z(4,I-1)) /DEL2X                                   00006890
      GO  TO  515                                                               00006900
C                                                    GENERAL EQUATIONS          00006909
  545 FEFE  =  - WP + WFE(I) * Z(1,I)                                           00006910
      S11  =  ENF /RHOX(I)                                                      00006920
      S5  =  S11*Z(2,I) + GAMA(I)*Z(1,I) + WTHD(I)*Z(3,I)                       00006930
      S6  =  UP + WFE(I)*Z(3,I)                                                 00006940
      EKTH  =  S11 * FETH(I) + GAMA(I) * FEFE                                   00006950
      ENFE(I)=  D(I) *(S6 + POI*S5) - ENT(I)                                    00006960
      EMTH(I)=  POI*Z(4,I) + EK(I)*S3*EKTH - S1*EMT(I)                          00006970
      ENTH(I)=  D(I) *(S5 + POI*S6) - ENT(I)                                    00006980
      ENFT(I)=  D(I)*S4 *(VP - GAMA(I)*Z(2,I) - S11*Z(1,I) )                    00006990
      EMFT(I)=  EK(I)*S4 *(-S11*FEFE + FETHP - GAMA(I)*FETH(I) + .5 *           00007000
     1 (WTHD(I) - WFE(I)) * (S11*Z(1,I) + VP + GAMA(I)*Z(2,I)) )                00007010
C                                                                               00007016
  548 S15  =  DNA(I) /A0                                                        00007017
      S7  =  S15 * S3                                                           00007018
      S9  =  E1(I) * ALF(I) * T(I) /S1                                          00007019
      S8  =  S12 * F1(I)                                                        00007020
      S10  =  S8 * S15 * EMT(I) /EK(I)                                          00007021
      GO  TO  550                                                               00007022
C                                                    SET FOR 2ND ST -SSES       00007023
  549 S15  =  DNA2(I) /A0                                                       00007024
      S7  =  S15 * S3                                                           00007025
      S9  =  E2(I) * T2(I) /S1                                                  00007026
      S8  =  S12 * E2(I)                                                        00007027
      S10  =  S8 * S15 * EMT(I) /EK(I)                                          00007028
C                                                                               00007029
  550 IF(I - 1) 565,551,565                                                     00007030
  551 IF(IBCT - 9) 552,553,559                                                  00007031
  552 S13  =  2.                                                                00007032
      GO  TO  572                                                               00007033
C                                                                               00007039
  553 S6  =  S15 /EK(I) *(Z(4,I) + EMT(I))                                      00007040
```

Deflections and Internal Loads (Cont)

```
      S21  =  Z(3,I)                                                    00007043
      S22  =  Z(4,I)                                                    00007044
C                                        CALCULATE CLOSED SHELL STRESSES 00007049
  554 IF(ENF - 1.) 555,556,557                                          00007050
  555 G(1)  =  S8 *(S2 *(UP  + WFE(I) * S21) + S6) - S9                 00007051
      G(2)  =  G(1)                                                     00007052
      G(3)  =  0.                                                       00007053
      GO  TO  578                                                       00007060
  556 G(1)  =  S8 *(POI * VP  + S6) - S9                                00007061
      G(2)  =  S8 *(VP  + S6 /POI) - S9                                 00007062
      G(3)  =  0.                                                       00007063
      GO  TO  578                                                       00007064
  557 G(1)  =  S8 *(S2 * UP  + POI*ENF*VP  + S6) - S9                   00007070
      G(2)  =  S8 *(S2 * UP  + ENF*VP  + S6 /POI) - S9                  00007071
      G(3)  =  S8*ENF *(S15 /(2.-ENF**2) * S22 /EK(I) - UP  * S1/2.)    00007072
      GO  TO  578                                                       00007074
  559 S13  =  1.                                                        00007080
      GO  TO  572                                                       00007081
  565 IF(I - N) 559,566,559                                             00007085
  566 IF(IBCB - 9) 552,553,559                                          00007086
  572 S6  =  S4 * (S15/2. *(3. * WTHD(I) - WFE(I)) + 1.)                00007160
      IF(IXL .NE. 0)  GO TO 574                                         00007165
      QFE(I) = S20 *(GAMA(I) *(Z(4,I) - EMTH(I))+EM6(4) + ENF/RHOX(I) * 00007170
     1 EMFT(I) * S13)                                                   00007180
C                                   CALCULATE OPEN AND GEN. STRESSES    00007189
  574 DO    575  K = 1,3                                                00007190
      DO    575  L = 1,4                                                00007200
  575 EM4(K,L)  =  0.                                                   00007210
      S11 = ENF/RHOX(I)                                                 00007215
      EM4(1,1)  =  S8                                                   00007220
      EM4(2,1)  =  POI * S8                                             00007230
      EM4(2,3)  =  - S7  * GAMA(I) * S8                                 00007240
      EM4(3,2)  =  S6 * S8                                              00007250
      EM4(3,3)  =  S15 * S1 * S11 * S8                                  00007260
      G2(1)  =  S10 - S9                                                00007270
      G2(2)  =  POI * S10 - S9                                          00007280
      G2(3)  =  0.                                                      00007290
      B2(1,1)  =  POI * GAMA(I) * S8                                    00007300
      B2(1,2)  =  POI * S11 * S8                                        00007310
      B2(1,3)  = (WFE(I) + POI * WTHD(I) ) * S8                         00007320
      B2(1,4)  =  S15 /EK(I) * S8                                       00007330
      B2(2,1)  =  GAMA(I) * (1. + S7*WFE(I)) * S8                       00007340
      B2(2,2)  =  S8 * S11 *(1. + S7*WTHD(I))                           00007350
```

Deflections and Internal Loads (Cont)

```
      B2(2,3)   =  S8 *(WTHD(I) + POI*WFE(I) + S7 * S11 **2)               00007360
      B2(2,4)   =  B2(1,4) * POI                                             00007370
      B2(3,1)   =  S8 * S4 * S11 *(S15/2. *(WTHD(I) - 3.*WFE(I)) - 1.)      00007380
      B2(3,2)   =  - EM4(3,2) * GAMA(I)                                      00007390
      B2(3,3)   =  - S8 * S1 * S11 * S15 * GAMA(I)                           00007400
      B2(3,4)   =  0.                                                        00007410
      CALL MMY  (3,4,1,EM4,EM6,G)                                            00007420
      CALL MMY  (3,4,1,B2,Z(1,I),EC)                                         00007430
      CALL MAD  (3,1,G,EC,G)                                                 00007440
      CALL MAD  (3,1,G,G2,G)                                                 00007450
  578 IF( IXL ) 600,579,600                                                  00007525
C                                                                            00007528
C                                         SAVE SOLUTIONS, 1ST STRESSES       00007529
  579 USUM(I)   =  Z(1,I)                                                    00007530
      VSUM(I)   =  Z(2,I)                                                    00007531
      WSUM(I)   =  Z(3,I)                                                    00007532
      EMFE(I)   =  Z(4,I)                                                    00007533
      SIGFE(I)   =  G(1)                                                     00007534
      SIGTH(I)   =  G(2)                                                     00007535
      SIGFT(I)   =  G(3)                                                     00007536
      GO  TO  620                                                            00007545
C                                                                            00007568
C                                                 SAVE 2ND STRESSES          00007569
  600 SGFE2(I)   =  G(1)                                                     00007570
      SGTH2(I)   =  G(2)                                                     00007571
      SGFT2(I)   =  G(3)                                                     00007572
      GO  TO  1000                                                           00007574
  620 IF(I .NE. 1) GO TO 630                                                 00007575
      IF(IBCT - 9) 640,1000,640                                              00007576
  630 IF(I .NE. N) GO TO 640                                                 00007577
      IF(IBCB .EQ. 9) GO TO 1000                                             00007578
  640 X(1,I)   =   2. * ROP * EMFT(I) - ENF * EMTH(I)                        00007579
 1000 CONTINUE                                                               00007580
C                                                                            00007581
      IF( STRI ) 1001,1005,1001                                              00007582
 1001 IF (IXL) 1005,1002,1005                                                00007583
C                                                                            00007585
C                                      SET POI AND IND. FOR 2ND STRESSES     00007588
 1002 POIX   =   POI                                                         00007589
      POI   =   POI2                                                         00007590
      IXL   =   1                                                            00007591
      GO  TO  499                                                            00007592
C                                                                            00007598
```

Deflections and Internal Loads (Cont)

```
C                                SOLVE FOR TRANSVERSE SHEARS         00007599
 1005 DO 1060  I = 1,N                                               00007600
      IF(I .NE. 1) GO TO 1020                                        00007610
      EMFTP  =  (-EMFT(3) + EMFT(2) + 3. *(EMFT(2)-EMFT)) /DEL2X     00007620
      IF(IBCT - 9) 1055,1010,1055                                    00007630
 1010 EMFEP  =  (-EMFE(3) + EMFE(2) + 3. *(EMFE(2)-EMFE)) /DEL2X     00007670
      EMTHP  =  (-EMTH(3) + EMTH(2) + 3. *(EMTH(2)-EMTH)) /DEL2X     00007680
 1015 QFE(I)=  ELAM2 * (EMFEP + ENF * EMFTP)                          00007690
      QTH(I)=  ELAM2 * (EMFTP - ENF * EMTHP)                          00007700
      GO   TO 1060                                                   00007710
 1020 IF(I .NE. N) GO TO 1050                                        00007730
      EMFTP = (EMFT(N-2)-EMFT(N-1) - 3.*(EMFT(N-1)-EMFT(N))) /DEL2X  00007740
      IF(IBCB - 9) 1055,1030,1055                                    00007750
 1030 EMFEP = (EMFE(N-2)-EMFE(N-1) - 3.*(EMFE(N-1)-EMFE(N))) /DEL2X  00007760
      EMTHP = (EMTH(N-2)-EMTH(N-1) - 3.*(EMTH(N-1)-EMTH(N))) /DEL2X  00007770
      GO  TO  1015                                                   00007780
 1050 EMFTP  =  (EMFT(I+1) - EMFT(I-1)) /DEL2X                       00007900
 1055 QTH(I)  =  ELAM2 /RHOX(I) *(X(1,I) + RHOX(I) * EMFTP )          00007910
 1060 CONTINUE                                                       00007920
C                        SAVE FOURIER COMPONENTS ON TAPE 8           00008999
      WRITE  (8)  N, (USUM(I), I = 1,2550), DEL, XSI, R              00009010
 2000 CONTINUE                                                       00009020
      POI  =  POIX                                                   00009045
      WRITE  (8)   S1                                                00009050
      REWIND  3                                                      00009055
C                                                                    00009059
      IF( PFLAG ) 2005,2010,2010                                     00009060
 2005 WRITE (6, 2006)                                                00009061
 2006 FORMAT(/// 10X, 19HLEAVING INTLD, LNK6   )                     00009062
 2010 RETURN                                                         00010000
      END                                                            00010001
```

Deflections and Internal Loads (Cont)

```
$IBFTC FSUMS                                                              1
C     VARIABLE THETA, SUMMING                        6J-148  ** LINK 7  00000010
C                                                                        11
      SUBROUTINE  SUMS                                                   12
C                                                                        13
      DIMENSION    SUMN(2550), ENFOR(4), THETA(11), ENFI(11)          00000300
C                                                                       399
      EQUIVALENCE      (DA(1),  EKK  ),(DA(2),   AO   ),(DA(3),  HO   ),00000340
     1(DA(4),   EO   ),(DA(5),  SIGO ),(DA(6),  PIXI  ),(DA(7), PTHI  ),00000341
     2(DA(8),  SUM   ),(DA(9),  ENFO ),(DA(10), ENFI  ),(DA(21), ENFOR),00000342
     3(DA(25), THETA ),                                                 343
     4(SDA(15),  DEL ),(SDA(1976),  R),(SDA(2498), XSI)               00000344
C                                                                       349
      COMMON    DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,   00000350
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                              0 -  351
      COMMON     SDA(3225), ZO,Z,    A2, B2, C2, G2                   00000355
      DIMENSION USUM(150),VSUM(150),WSUM(150), EMFE(150), EMTH(150),  00000360
     1  EMFT(150), ENFE(150), ENTH(150), ENFT(150), SIGFE(150),       00000361
     2  SIGTH(150), SIGFT(150), QFE(150), QTH(150), SGFE2(150),       00000362
     3  SGTH2(150), SGFT2(150), DEL(1), XSI(150), R(150)              00000363
C                                                                       979
      JKL = 1                                                           985
      IF  (THETA(2) .EQ. -1.E+10)        GO TO  602                   00000990
      NOTP  =  3                                                        992
C                                       TRANSFER FOURIER COMPONENTS TO 3 00000999
      DO   520   LL = 1,KKE                                            1000
      BACKSPACE  8                                                     1010
      BACKSPACE  8                                                     1020
      READ (8)    N, (USUM(I), I = 1,2550), DEL, XSI, R               00001030
  520 WRITE (3)   N, (USUM(I), I = 1,2550), DEL, XSI, R               00001040
C                                                                      2499
  600 REWIND  3                                                        2500
  602 SL1  =  1.                                                       2509
      S5 = ENF * THETA(JKL) * 0.0174532925                            00002510
      COSNT  =  COS( S5 )                                              2511
      SINNT  =  SIN( S5 )                                              2512
      THETX  =  THETA( JKL )                                           2513
C                                                                      2518
C                                                                      2519
  610 DO   850   KK = 1,KKE                                            2520
      IF( SL1 ) 615,753,615                                            2522
  615 IF  (THETA(2) .NE. -1.E+10)        GO TO  700                   00002524
      BACKSPACE  8                                                     2526
```

Variable Theta, Summing

```
      BACKSPACE  8                                                        2528
      NOTP  =  8                                                          2530
C                                   READ FOURIER COMPONENTS /REGION   00002534
  700 READ (NOTP)  N, (USUM(I), I =1,2550), DEL, XSI, R               00002535
      IF(SUM .LT. 0.) GO TO 730                                           2538
  710 DO  720     I = 1,N                                                 2540
      USUM(I)   =  USUM(I) * COSNT                                        2550
      VSUM(I)   =  VSUM(I) * SINNT                                        2560
      WSUM(I)   =  WSUM(I) * COSNT                                        2570
      EMFE(I)   =  EMFE(I) * COSNT                                        2580
      EMTH(I)   =  EMTH(I) * COSNT                                        2590
      EMFT(I)   =  EMFT(I) * SINNT                                        2600
      ENFE(I)   =  ENFE(I) * COSNT                                    0 0 2610
      ENTH(I)   =  ENTH(I) * COSNT                                        2620
      ENFT(I)   =  ENFT(I) * SINNT                                        2630
      SIGFE(I) =  SIGFE(I) * COSNT                                        2640
      SGFE2(I) =  SGFE2(I) * COSNT                                    0 0 2645
      SIGTH(I) =  SIGTH(I) * COSNT                                    0 0 2650
      SGTH2(I) =  SGTH2(I) * COSNT                                        2655
      SIGFT(I) =  SIGFT(I) * SINNT                                        2660
      SGFT2(I) =  SGFT2(I) * SINNT                                    0 0 2665
      QFE(I)    =  QFE(I) * COSNT                                       0 2670
  720 QTH(I)    =  QTH(I) * SINNT                                         2680
      GO  TO  758                                                         2690
C                                              PRINT RESULTS          00002709
  730 WRITE (6, 733) KK, THETX, ENF, (I, USUM(I), VSUM(I), WSUM(I),   00002710
     1 EMFE(I), EMTH(I), EMFT(I), I = 1,N)                            00002711
  733 FORMAT(1H1, 12X,   6HREGION, I3, 41H, DEFLECTIONS AND INTERNAL LOA00002720
     1DS, THETA =,1PE12.4,3X,5HENF =1PE12.4                           00002721
     2 /// 3X,1HI, 6X,4HU(I),9X,4HV(I),9X,4HW(I),8X,6HM(PHI),6X,      00002722
     3 8HM(THETA),3X,12HM(PHI,THETA) // (I4, 6E13.4) )                00002723
C                                                                         2739
      WRITE (6, 735) (I, QFE(I), QTH(I), ENFE(I), ENTH(I), ENFT(I),   00002740
     1 I = 1,N)                                                           2745
  735 FORMAT (1H1,2X,1HI,5X,6HQ(PHI),6X,8HQ(THETA),6X,6HN(PHI),6X,    00002750
     1 8HN(THETA), 3X,12HN(PHI,THETA) // (I4, 1P5E13.4) )             00002755
C                                                                         2759
      WRITE (6, 737) (I, SIGFE(I), SIGTH(I), SIGFT(I), SGFE2(I),      00002760
     1 SGTH2(I), SGFT2(I),  I = 1,N)                                  0 0-2765
  737 FORMAT (1H1,2X,1HI,4X,8HSIG(PHI),4X,10HSIG(THETA),2X,           00002770
     1 13HSG(PHI,THETA),2X,8HSG2(PHI), 4X,10HSG2(THETA),2X,           00002775
     2 14HSG2(PHI,THETA)//       (I4, 1P6E13.4) )                     00002780
C                                                                         2829
```

Variable Theta, Summing (Cont)

```
740 IF( SUM ) 850,850,750                                                 2830
750 NTH  =  NTH - 1                                                       2840
    IF (NTH) 753,751,753                                                  2850
751 IFR = IFR + 1                                                         2852
    IF (ENFOR(IFR)) 752,887,887                                         0 2854
752 ENF = -1.0                                                            2856
    GO TO 890                                                             2858
753 READ  (NTPW) KK,N,THETX,(USUM(I), I = 1,2550)                     00002860
755 DO 756 I = 1,N                                                        2900
    USUM(I)  =  SQ3 * USUM(I)                                             2910
    VSUM(I)  =  SQ3 * VSUM(I)                                             2920
    WSUM(I)  =  SQ3 * WSUM(I)                                             2930
    EMFE(I)  =  SQ4 * EMFE(I)                                             2940
    EMTH(I)  =  SQ4 * EMTH(I)                                             2950
    EMFT(I)  =  SQ4 * EMFT(I)                                             2960
    QFE(I)   =  SQ6 * QFE(I)                                              2970
    QTH(I)   =  SQ6 * QTH(I)                                              2980
    ENFE(I)  =  SQ6 * ENFE(I)                                             2990
    ENTH(I)  =  SQ6 * ENTH(I)                                             3000
756 ENFT(I)  =  SQ6 * ENFT(I)                                             3010
    GO  TO  730                                                           3020
758 IF (SL2) 815,820,815                                                  3040
815 WRITE (NTPW) KK,N,THETA(JKL),(USUM(I),I = 1,2550), DEL, XSI, R    00003060
    IF(SUM .EQ. 0.)  GO TO 755                                            3065
    GO  TO  850                                                           3070
C                                                                         3080
820 READ  (NTPR) KK,N,THETX,(SUMN(I), I = 1,2550), DEL, XSI, R        00003090
    DO   830    I = 1,N                                                   3100
    USUM(I)    =  USUM(I)  +  SUMN(I)                                 0 0 3101
    VSUM(I)    =  VSUM(I)  +  SUMN(I+150)                             00003102
    WSUM(I)    =  WSUM(I)  +  SUMN(I+300)                             00003103
    EMFE(I)    =  EMFE(I)  +  SUMN(I+450)                             00003104
    EMTH(I)    =  EMTH(I)  +  SUMN(I+600)                             00003105
    EMFT(I)    =  EMFT(I)  +  SUMN(I+750)                             00003106
    ENFE(I)    =  ENFE(I)  +  SUMN(I+900)                             00003107
    ENTH(I)    =  ENTH(I)  +  SUMN(I+1050)                            00003108
    ENFT(I)    =  ENFT(I)  +  SUMN(I+1200)                            00003109
    SIGFE(I)   =  SIGFE(I) +  SUMN(I+1350)                            00003110
    SIGTH(I)   =  SIGTH(I) +  SUMN(I+1500)                            00003111
    SIGFT(I)   =  SIGFT(I) +  SUMN(I+1650)                            00003112
    QFE(I)     =  QFE(I)   +  SUMN(I+1800)                            00003113
    QTH(I)     =  QTH(I)   +  SUMN(I+1950)                            00003114
    SGFE2(I)   =  SGFE2(I) +  SUMN(I+2100)                            00003115
```

Variable Theta, Summing (Cont)

```
      SGTH2(I)  =  SGTH2(I) +  SUMN(I+2250)                          00003116
  830 SGFT2(I)  =  SGFT2(I) +  SUMN(I+2400)                          00003117
      GO  TO  815                                                        3120
  850 CONTINUE                                                           3125
  860 JKL = JKL + 1                                                      3130
      IF (THETA(JKL)) 880,600,600                                        3140
  880 IF(SUM .LT. 0.) GO TO 888                                          3150
      REWIND  NTPW                                                       3200
      IF (ENF .EQ. ENFOR(IFR))  GO TO 900                            00003210
  887 NX  =  NTPR                                                        3220
      NTPR  =  NTPW                                                      3230
      NTPW  =  NX                                                        3240
  888 KLM  =  KLM + 1                                                    3243
      ENF = ENFI(KLM)                                                    3245
      SL2  =  0.0                                                        3247
  890 RETURN                                                             3250
  900 IF( SUM ) 910,890,910                                              3260
  910 SL1  =  0.                                                         3270
      NTH = (JKL-1) * KKE                                                3272
      GO  TO   610                                                       3280
      END                                                                3310
```

Variable Theta, Summing (Cont)

```
$IBFTC CRT
C     CRT PACKAGE                                      6J-148  ** LINK 8   00000010
C                                                                                11
      SUBROUTINE  PIX                                                            20
C                                                                                30
      DIMENSION  USUM(150), VSUM(150), WSUM(150), EMFE(150), EMTH(150), 00000040
     1 EMFT(150), ENFE(150), ENTH(150), ENFT(150), SIGFE(150),          00000050
     2 SIGTH(150), SIGFT(150), QFE(150), QTH(150), SGFE2(150),          00000060
     3 SGTH2(150), SGFT2(150)                                                    70
      DIMENSION  XSI(150), R(150), STAX(150)                                     80
C                                                                                90
      COMMON    DA(35), NTPW, NTPR, KTPW, KTPR, SL2, ELAM2, S1, S2,     00000100
     1  KKE, SQ3, SQ4, SQ6, ENF, IFR, KLM                               0 0  101
      COMMON     SDA(3225), ZO,Z,    A2, B2, C2, G2                     00000110
C                                                                               120
      EQUIVALENCE (SDA(2498), XSI),              (SDA(1976),   R)       00000130
C                                                                               140
      CALL SCOUTV                                                               150
C                                                                               160
      DO 300 IX = 1,KKE                                                         200
      READ (NTPW)KK,N,THEX,(USUM(I),I=1,2550), DEL, XSI, R              00000210
C                                                                               220
      DO 25 II = 1,N                                                            222
   25 STAX(II) = II                                                             224
C                                                                               226
   29 WRITE (16,30) IX                                                          230
      WRITE (16,35) DEL                                                         240
   30 FORMAT (1H1,38X,7HREGION ,I3,10X,14HSHELL GEOMETRY)               00000250
   35 FORMAT (20X,17HAXIAL LENGTH VS R,10X,6HDEL = ,F7.4,10X, 20H* - STA00000260
     1TION LOCATION)                                                            270
   40 CALL LINEG (1H*, R, XSI, N, $40)                                          280
      WRITE (16,45)                                                             290
   45 FORMAT(36X,38HR   RADIUS OF PARALLEL CIRCLE (INCHES) )            00000300
C                                                                               310
      WRITE (16,55) IX                                                          320
      WRITE (16,60)                                                             330
   55 FORMAT (1H1,34X,7HREGION ,I3,10X,23HDISPLACEMENTS IN INCHES )     00000340
   60 FORMAT (10X,18H+ - U (MERIDIONAL),10X,23HO - V (CIRCUMFERENTIAL), 00000350
     1 10X,28H* - W (NORMAL TO REF. SURF.) )                            0^00^360
   65 CALL LINEG (1H+, STAX, USUM, N)                                           370
      CALL LINEG (1HO, STAX, VSUM, N)                                           380
      CALL LINEG (1H*, STAX, WSUM, N, $65)                              0 0  390
      WRITE (16,70)                                                             400
```

CRT Package

```
   70 FORMAT (47X,15HSTATION NUMBERS)
C
      WRITE (16,75) IX
      WRITE (16,80)
   75 FORMAT (1H1,34X,7HREGION ,I3,10X,23HMEMBRANE FORCES (LB/IN) )
   80 FORMAT (10X,18H+ - N (MERIDIONAL),10X,23HO - N (CIRCUMFERENTIAL),
     1 10X,27H* - N (INPLANE SHEAR FORCE) )
   85 CALL LINEG (1H+, STAX, ENFE, N)
      CALL LINEG (1HO, STAX, ENTH, N)
      CALL LINEG (1H*, STAX, ENFT, N, $85)
      WRITE (16,70)
C
      WRITE (16,90) IX
      WRITE (16,95)
   90 FORMAT (1H1,33X,7HREGION ,I3,10X,24HBENDING MOMENTS IN-LB/IN )
   95 FORMAT (16X,18H+ - M (MERIDIONAL),10X,23HO - M (CIRCUMFERENTIAL),
     1 10X,16H* - M (TWISTING) )
  100 CALL LINEG (1H+, STAX, EMFE, N)
      CALL LINEG (1HO, STAX, EMTH, N)
      CALL LINEG (1H*, STAX, EMFT, N, $100)
      WRITE (16,70)
C
      WRITE (16,105) IX
      WRITE (16,110)
  105 FORMAT (1H1,30X,7HREGION ,I3,10X,29HTRANSVERSE SHEAR FORCES LB/IN)
  110 FORMAT (29X,18H+ - Q (MERIDIONAL),10X,23HO - Q (CIRCUMFERENTIAL))
  115 CALL LINEG (1H+, STAX, QFE, N)
      CALL LINEG (1HO, STAX, QTH, N, $115)
      WRITE (16,70)
C
      WRITE (16,120) IX
      WRITE (16,125)
  120 FORMAT (1H1,28X,7HREGION ,I3,10X,33HSTRESSES AT THE INNER SURFACE
     1PSI )
  125 FORMAT (15X,20H+ - SIG (MERIDIONAL),10X,25HO - SIG (CIRCUMFERENTIA
     1L),10X,15H* - SIG (SHEAR) )
  130 CALL LINEG (1H+, STAX, SIGFE, N)
      CALL LINEG (1HO, STAX, SIGTH, N)
      CALL LINEG (1H*, STAX, SIGFT, N, $130)
      WRITE (16,70)
C
      WRITE (16,135) IX
      WRITE (16,140)
```

CRT Package (Cont)

```
 135 FORMAT (1H1,28X,7HREGION ,I3,10X,33HSTRESSES AT THE OUTER SURFACE 00000840
    1PSI )                                                                  850
 140 FORMAT (15X,20H+ - SIG (MERIDIONAL),10X,25HO - SIG (CIRCUMFERENTIA00000860
    1L),10X,15H* - SIG (SHEAR) )                                            870
 145 CALL LINEG (1H+, STAX, SGFE2, N)                                       880
     CALL LINEG (1HO, STAX, SGTH2, N)                                       890
     CALL LINEG (1H*, STAX, SGFT2, N, $145)                           0 00 900
     WRITE (16,70)                                                          910
C                                                                           920
 300 CONTINUE                                                               930
C                                                                           940
     RETURN                                                                 950
     END                                                                    960
```

CRT Package (Cont)

APPENDIX IIIB

PROGRAM NOMENCLATURE

In this section are listed all variables that are used in the FORTRAN IV program and their related definitions. The appropriate mathematical equivalents from Section 1.0. are included where applicable.

<u>A</u>

A		4-x-4 matrix, defined in Equation 66, Section 1.12; constant in conics computation
AO	a	Reference length (L)
A2		4-x-4 matrix, used to preserve A matrix for meridional station 2
A2CØS		$Cos^2\theta_1$, variable in conics computations
A2SIN		$Sin^2\theta_1$, variable in conics computations
AA2		Constant in conics computation
ACCØS		Variable in parabola computation
ACØSP		COS(APHI), see APHI
AI		4-x-4 matrix, used to preserve A matrix for bottom discontinuity point
AJI		Used in computing X distance for general discrete points, GEOM
AK		Used in computing X distance for general discrete points, GEOM
ALF	α	Thermal expansion coefficient for N summations
ALF1		Thermal expansion coefficient data for material 1

ALF2		Thermal expansion coefficient data for material 2
ALF3		Thermal expansion coefficient data for material 3
ALFA		DEL/DPREV
ALFA2		ALFA **2
ALFI		Inner coefficient of thermal expansion/layer
ALFϕ		Outer coefficient of thermal expansion/layer
AM		Value of signed variable
AMB2		$A^2 - B^2$ constant in hyperbola computation
AMU		Sign control variable in conics
ANGSP		Angle span for sphere-toroid, GEOM
ANX		Angle between the generator and axis of revolution, cone-cylinder, GEOM
APB2		$A^2 + B^2$ constant in ellipse computation
APHI		GEOM parameter for computing X distance in sphere-toroid shape
ASI		4-x-4 matrix, used to preserve A matrix at top, for open shell or discontinuity
ASINP		SIN(APHI) see APHI
ASN		4-x-4 matrix, used to preserve A matrix at bottom, for open shell or discontinuity
ASSIN		$\mathrm{Sin}^2\theta_1$, variable in parabola computation
AXL		Axial surface length
B		
B	b	4-x-4 matrix, defined in Equation 66, Section 1.12; constant in conics

B2		4-x-4 matrix, used to preserve A matrix for station 2; also used in stresses
B2MSMS		Variable in hyperbola computation
BB2		B^2
BCD		Three title cards read in executive program
BCIB		Boundary condition indicator, bottom, (i = N) SDA data
BCIBM		Boundary condition indicator, bottom, (i = N) GDA data
BCIT		Boundary condition indicator, top (i = 1) SDA
BCITP		Boundary condition indicator, top (i = 1) GDA
BCØSP		COS(PHI0), sphere-toroid, GEOM, see PHI0
BETA		Cylindrical coordinate variable describing conics
BETADP		Second derivative of BETA
BETAP		Derivative of BETA with respect to angular variable of BETA description
BI		4-x-4 matrix, used to preserve B matrix for bottom discontinuity
BJR		Index in conics when subdividing cylindrical coordinate range
BM		Value of signed variable
BMU		Sign control variable in conics
BØT4		4-x-1 matrix, used to preserve solutions for bottom discontinuity point
BP	b^1	First derivative of the membrane stiffness
BPHI		GEOM parameter used in computing X distances for sphere-toroid
BQ		Same as B2, see COMMON region, INTLD

BS1		4-x-4 matrix, used to preserve B matrix at top, for open shell or discontinuity
BSINP		SIN(PHI0), see PHI0
BSN		4-x-4 matrix, used to preserve B matrix at bottom, open shell or discontinuity
BTA2		Variable in the conics option
BTAP2		Variable in the conics option
C		
C		4-x-4 matrix, defined in Equation 66, Section 1.12
C2		4-x-4 matrix, used to preserve C matrix for station 2
CHI		4-x-4 discontinuity matrix, Equation 57
CHI1		4-x-4 discontinuity matrix, Equation 58
CHI2		4-x-4 discontinuity matrix, Equation 59
CI		4-x-4 matrix, used to preserve C matrix for bottom discontinuity
CØDIMA		Parabolic curve fitting subroutine (see page 178, Section 37.3)
CØSFI		COS(ANX) used to compute WTH for cone-cylinder, GEOM
CØSNT		COS($\eta\theta$) used in Fourier summing
CS1		4-x-4 matrix, used to preserve C matrix at top, for open shell or discontinuity
CSN		4-x-4 matrix, used to preserve C matrix at bottom, for open shell or discontinuity
D		
D	d	Membrane stiffness (dimensionless in program), Equation 33
DA		General data area, read in executive program

DAL	Section properties data/region, read in DATLYR subroutine
DATLDS	Data loads subroutine sets PN, PFE, PTH, TBT, TTP (pressure and temperature loads)
DATLNK	Regional data read subroutine, sub-executive program for GEOM, DATLDS, DATLYR
DATLYR	Section properties subroutine
DDL	Used in GEOM (2040)
DECRD	Data read subroutine (see explanation page 79)
DEL Δ	Interval size between meridional stations
DEL2X	2. * DEL
DELSQ	DEL ** 2
DELTH	Circumferential increment for Fourier summing for loads
DENM	Denominator for computing GAMA in GEOM subroutine
DENMP	Denominator quantity for finite difference first derivatives in discrete points option
DENOM	Denominator for computing WFE in GEOM subroutine
DENOMP	Denominator for finite difference and derivatives in the discrete points option
DINTRP	Linear double interpolation subroutine
DIS1, 2, 3, 4	Discontinuity matrices formed at top discontinuity point in PANDX
DLD	Data area in DATLDS subroutine/region
DLR	Used in GEOM (2060); intermediate radial increment in discrete point option
DLS	Used in GEOM (2062); intermediate arc length increment in discrete point option

DLT		Used in GEOM (2034); axial increment of input in discrete point option
DNA		Distance from neutral axis
DNA2		DNA for second surface where stresses are computed
DNAX		DNA at combined thickness and temperature stations
DP	d^1	Derivative of the bending stiffness
DPREV		DEL for previous region
E		
E		4-x-4 matrix (see Equation 41)
E0	E_o	Reference Young's modulus (P/L^2)
E1		Modulus of elasticity for N summations
E2		E1 for second surface where stresses are computed
EC		4-x-1 auxiliary storage matrix
ECX	E_{cc}	Eccentricity of reference surface at discontinuity junction
EI		Inner modulus of elasticity/station/layer
EIFH		Thickness indicator + 1 = constant all stations in a layer, - 1 = discrete values given at THSTA
EJI		4-x-4 matrix, used to preserve J matrix for bottom discontinuity (Equation 51) B & R
EK	d	Bending stiffness (dimensionless in program), Equation 34
EKK		Number of regions
EKTH		Fourier coefficient for bending distortion (Equation 24) B & R
ELAM2	λ^2	(H0/A0) ** 2
ELAY		Number of layers (six maximum)

ELD		4-x-1 matrix used at top discontinuity point
EM		Number of radii entered for discrete point geometry case
EM1	Ω	4-x-4 diagonal boundary force matrix ($i = 1$) (Equation 47)
EM1N	Ω	4-x-4 diagonal boundary force matrix ($i = N$) (Equation 47)
EM1X	Ω	EM1 when read as data in GDA area
EM2	H	4-x-4 matrix (Equation 50)
EM3	Λ	4-x-4 diagonal boundary displacement matrix ($i = 1$) (Equation 47)
EM3N	Λ	4-x-4 diagonal boundary displacement matrix ($i = N$) (Equation 47)
EM3X		EM3 in GDA data area
EM4	J	4-x-4 boundary matrix (Equation 51)
EM5	ℓ	4-x-1 boundary matrix ($i = 1$) (Equation 47)
EM5N	ℓ	4-x-1 boundary matrix ($i = N$) (Equation 47)
EM5X		EM5 in GDA data area
EM6	f	4-x-1 boundary matrix (Equation 51)
EMAT		Material indicator/layer (1, 2, or 3)
EMD	M_D	Moment at bottom discontinuity point
EMFE	m_ξ	Bending moment per unit length, meridional direction
EMFEP		First derivative of EMFE
EMFT	$m_{\xi\theta}$	Bending moment, shear
EMFTP		First derivative of EMFT
EMK		Spring value-moment at location SPRL
EMN1		EM1N, when read as data in GDA area

EMN3		EM3N, when read as data in GDA area
EMN5		EM5N, when read as data in GDA area
EMT	m_T	Temperature moment, Equation 36, Section 1.7
EMTH	m_θ	Bending moment per unit length, circumferential direction
EMTHP		First derivative of EMTH
EMTP		First derivative of EMT
EN	N	Number of meridional points/region (150 maximum)
ENA1		Number of thermal expansion coefficients given for first material (10 maximum)
ENA2		Number of thermal expansion coefficients given for second material (10 maximum)
ENA3		Number of thermal expansion coefficients given for third material (10 maximum)
ENE1		Number of Young's moduli given for first material (10 maximum)
ENE2		Number of Young's moduli given for second material (10 maximum)
ENE3		Number of Young's moduli given for third material (10 maximum)
ENF	n	Current Fourier component
ENFO		Initial Fourier component
ENFE	t_ξ	Fourier component for membrane force, meridional direction
ENFI		Subsequent Fourier components (10 maximum)
ENFØR		Fourier component print values (3 possible)
ENFT	$t_{\xi\theta}$	Fourier coefficient for membrane shear force

ENMAT		Number of materials (3 maximum)
ENϕGR		Number of gradient stations (10 maximum)
ENϕT		Number of stations for temperatures given in TBOT and TTOP
ENϕTH		Number of stations for thicknesses given in TH (20 maximum)
ENT	t_T	Temperature load (nondimensional) Equation 35, Section 1.7
ENTERP		Single, linear interpolation subroutine
ENTH		Number of theta values to use in Fourier summing for loads, also Fourier coefficient for membrane force, circumferential direction
Eϕ		Outer modulus of elasticity/station/layer
EX		Constant data indicator. Use only when SUM = 0. 0. = no constants, - = all constants, + 1 = section properties and temperature loads constant, + 2 = symmetrical pressure loads, no temperature loads. SDA(1)

F

F		4-x-4 matrix, see (Equation 41) B & R
FEFE	ϕ_ξ	Fourier coefficient for rotation, meridional
FETH	ϕ_θ	Fourier coefficient for rotation, circumferential
FETHP		First derivative of FETH
FI		4-x-1 matrix, used to preserve f matrix (Equation 51, Section 1.12) for bottom discontinuity point

G

G		4-x-1 matrix g in Equation 66, Section 1.12
G2		4-x-1 matrix, used to preserve g matrix for station 2, also used in stresses

GA		4-x-4 matrix, G in Equation 41, Section 1.8
GAM		Current GAMA value
GAM2		GAM ** 2
GAMA	γ	Geometry parameter at stations
GAMRX		Intermediate variable for sign check
GDA		Data area in GEOM subroutine/region
GECX		Eccentricity of reference surface at bottom discontinuity point
GEMK		Spring value - moment
GEØM		Geometry subroutine
GEØMI		GMI in SDA region
GI		4-x-1 matrix, used to preserve g matrix (Equation 66, Section 1.12 for bottom discontinuity point
GMI		Geometry indicator. 1. = cone-cylinder, 2. = sphere-toroid, 3. = general discrete points
GPSI	ψ	Angle of inclination at discontinuity (degrees)
GQ		4-x-1 matrix, used to preserve g matrix for station 2, see G2
GR		Values of gradients at GSTA stations and internal interfaces
GS1		4-x-1 matrix, used to preserve g matrix when I = 1 at open boundary or discontinuity
GSN		4-x-1 matrix, used to preserve g matrix when I = N at open boundary or discontinuity
GSPRL		Location of spring (one per region)
GSTA		Temperature gradient stations (same for each interface)

GUK		Spring value - ξ direction	
GVK		Spring value - θ direction	
GWK		Spring value - ζ direction	
H			
H0	h_o	Reference thickness (inches)	
HI		4-x-4 matrix, used to preserve H matrix (Equation 51, Section 1. 7) for bottom discontinuity point	
I			
I	i	Index, meridional station counter	
I1		Index	discrete point option
I2		Index	
IBCB		Fixed point value for BCIBM	
IBCT		Fixed point value for BCITP	
IBCX		Fixed point value, either IBCB or IBCT	
IERR		Error indicator from matrix inversion subroutine	
IFR		Counter, ENFOR subscript	
IGM		Fixed point value for GMI	
IGϕ		Computed GO TO index in DATLDS, EFN 420. = 1, pressures, = 2, temperatures	
II		DATLDS - subscript to send temperature values to TBT or TTP PIX - index and subscript for forming an array of station numbers; GEOM - Index, discrete point option	
IJD		Index	discrete point option
IJTD		Index	

IL	GEOM - DO index for EFN 80 DATLDS - TLOC subscript to pick up NDSTA for next ENF/load increment = 1
INA1, 2, 3	Fixed point form of ENA1, 2, 3
INC	Increment between temperature stations
INDC	Fixed point form of loads indicators
INE1, 2, 3	Fixed point form of ENE1, 2, 3
INTLD	Subroutine which computes deflections, internal loads and stresses
INV	Matrix inversion subroutine
IPRS	Fixed point form of PILD, the pressure indicator
IRGN	Region number in argument list of GEOM subroutine
ISDA	SDA location for storing pressures, incremented by PN dimension
ISEC	Region DO loop index in PANDX subroutine
ITB	TAB subscript for pressure tables, incremented by PNTB dimension
ITBT	Fixed point form of TIBT, bottom surface temperature indicator
ITTP	Fixed point form of TITP, top surface temperature indicator
IX	DATLDS - subscript used to store loads in SDA data area PIX - DO loop index for region counter
IXL	Path indicator in INTLD for second interface stress calculations
IXX	Fixed point form of material indicator/layer
IZ	Subscript for Z solution; used to step backwards through a region

J

J	DO loop index, DATLDS at EFN 440, etc.
JI	DO loop index, GEOM at EFN 78
JKL	THETA subscript in SUMS subroutine
JR	Index
JTD	Index } discrete point option
JTD1	Index

K

K	DO loop index, PANDX at EFN 265, etc.
K0	Subscript for separating stations and values in DATLDS tables
K1	Current table location in loads table
K2	Upper limit of table values for present Fourier component of load
KK	SUMS - DO loop index, region counter; PIX - region number read from tape and INTLD - DO loop index, region counter; GEOM
KKE	Fixed point form of EKK, number of regions
KLM	Subscript for setting ENF to next ENFI value
KP1	DO loop limit in GEOM at EFN 78
KS	Number of temperature stations set in DATLDS at EFN 312
KTPR KTPW	Tape number 12 or 13 where SDA data is stored. On subsequent passes during Fourier summing the number are interchanged
KX	Subscript of TAB used to pick up the number of stations in DATLDS

L

L	DO loop index, PANDX at EFN 265, etc.
L0	Set at zero to permit zero subscripting of P, X, and Z matrices in PANDX and INTLD
L1	Lower limit in DO loop for computing FETH in INTLD subroutine
LL	DO loop index, SUMS at EFN 520
LSP	Fixed point form of SPRL, spring location

M

M	Fixed point form of EM, number of general discrete points in GEOM
MAD	Matrix addition subroutine
MLN	Index; discrete point option
MM	DO loop upper level for discrete point geometry, GEOM at EFN 80
MM2	M—2
MMY	Matrix multiplication subroutine
MSP	Path indicator to skip stiffness calculations when there is no change from previous case
MSU	Matrix subtraction subroutine
MT	Fixed point form of the number of temperature stations, ENOT
MTH	Fixed point form of the number of thickness stations, ENOTH

N

N	Fixed point form of EN, the number of meridional stations/region

NFE	Number of meridional stations for Fourier summing of the loads
NLAY	Fixed point form of ELAY, the number of layers/region
NLAY1	Number of interfaces, ELAY + 1.
NMAT	Fixed point form of ENMAT, the number of materials
NN	DO loop upper level for RHOX calculation in GEOM
NØGR	Fixed point form of ENOGR, number of gradient stations
NØSTA	Number of stations where loads are given
NØTP	Tape number for Fourier components. 3 = several ENF's, 8 = one ENF value
NS	DO loop index, region number counter, DATLNK at EFN 1
NSM	Index; discrete point option
NTH	Fixed point forms of ENTH, number of thetas to sum
NTPR NTPW	Tape number 9 or 10 used during Fourier summing to store sums/region/theta
NX	Temporary save location when interchanging NTPR and NTPW

<u>Ø</u>

ØPEXQ	Optional error exit subroutine. Used to take square root of the absolute value of a negative argument in GEOM

<u>P</u>

P	Three-dimensional array (Equations 4, 4, 150) used to store the P matrices (Equation 74) at each meridional station/region
P0	4-x-4 matrix for P at the (N - 1)st station of previous region
PANDX	Subroutine for generating the P and X matrices of Equation 74

PD	P_D	Pressure at a point of discontinuity
PFE	P_ξ	Fourier component for load in the meridional direction
PFETB		Data table of PFE values, DLD data area
PFEX		Table location for PFE values for next Fourier component
PFLAG		Print indicator
PHI0		Initial opening angle from vertical axis for sphere or toroid
PHIN		Final opening angle from vertical axis for sphere or toroid
PI		Determinant value, in argument list of INV subroutine
PILD		Pressure indicator for type of data in tables, see explanation of DLD data
PIX		CRT subroutine
PIXI		CRT indicator; plots curves when nonzero
PM		COMMON location for preserving material properties data
PN	P	Fourier component for load in the normal direction
PNTB		Data table of PN values, DLD data area
PNX		Table location for PN values for next Fourier component
PØI	ν	Poisson's ratio for the inner layer
PØI2		Poisson's ratio for the second stress layer
PØIS		Poisson's ratio/layer in DAL data area
PØIX		Temporary storage location for POI in INTLD at EFN 1002
PRØ		Intermediate variable for a sign check in GAMA computation of discrete point option
PSI	ψ	Discontinuity angle at the bottom of a region (degrees)
PSI0	ψ_0	Angle at which load is applied at discontinuity point (degrees)

PSIM		4-x-1 matrix, moment at discontinuity point
PSIP		4-x-1 matrix, pressures at discontinuity point
PTH	P_θ	Fourier component for load in the circumferential direction
PTHI		Path indicator for multiple case jobs
PTHTB		Data table of PTH values, DLD data area
PTHX		Table location for PTH values for next Fourier component
<u>Q</u>		
QFE	$\hat{f}_\xi$	Transverse force per unit length in meridional direction
QTH	$\hat{f}_\theta$	Transverse force per unit length in circumferential direction
<u>R</u>		
R	r	Normal distance from shell to axis
RA1		Radius of cone or cylinder at station 1
RC		Radius of curvature of sphere or toroid
RCRV		Interpolated station values of meridional radius of curvature
RCRZ		Interpolated station values of circumferential radius of curvature
RCURV		Input values of meridional radius of curvature
RCURZ		Input values of circumferential radius of curvature
RFF		Standard form coordinate of conics offset from axis of revolution
RHØ		Current RHOX value set for each station in PANDX
RHØP		First derivative of RHO
RHOX	ρ	R/A0

RIPT	Discrete radii for general shell shape, GDA data area
RJ	Intermediate radii for better curve fitting of RIPT
RØFF	Offset distance of center of curvature from axis of revolution for toroids
RR	Intermediate radius designation at stations for smoothing in discrete points
RRJ	Intermediate radius designation for smoothing in discrete points

S

S	Followed by a number indicates a scalar quantity which is used in several equations or is more efficiently defined outside a DO loop. The name of the subroutine and nearest external formula number (EFN) is given except for those found in COMMON.
S1	COMMON, 1. - POI DATLDS: 610, 700, 710
S2	COMMON, 1. + POI DATLDS: 405
S3	DATLNK: 20, 40, 305 DATLDS: 401 PANDX: 100, 410, 450, 900 INTLD: 490
S4	DATLNK: 20, 40 PANDX: 3, 50, 900 INTLD: 490
S5	DATLNK: 20, 50 DATLDS: 5, 622, 625 SUMS: 602 DATLYR: 335 INTLD: 490, 545 PANDX: 100, 410
S6	DATLYR: 335 PANDX: 50 INTLD: 512, 545, 553, 572
S7	DATLYR: 335 PANDX: 50 INTLD: 548, 549
S8	DATLYR: 335 PANDX: 100, 410, 900 INTLD: 548, 549
S9	DATLYR: 347 PANDX: 100, 410 INTLD: 548, 549
S10	DATLYR: 305, 348 PANDX: 100, 410 INTLD: 548, 549
S11	DATLYR: 310, 348 PANDX: 100, 410 INTLD: 545, 575

S12	DATLYR: 305, 347 PANDX: 430
S13	DATLYR: 305, 348 PANDX: 430 INTLD: 552, 559
S15	PANDX: 100, 140 INTLD: 548, 549
S16	DATLYR: 348
S17	DATLYR: 347
S18	DATLYR: 348
S20	INTLD: 490
S21	INTLD: 553
S22	INTLD: 553
S91	DATLYR: 351
S92	DATLYR: 351
S93	DATLYR: 351
S94	DATLYR: 351
S101	DATLYR: 360
S102	DATLYR: 360
S103	DATLYR: 360
S104	DATLYR: 360
S105	DATLYR: 360
S106	DATLYR: 360
S107	DATLYR: 360
S108	DATLYR: 360
SARB	Discrete point option in GEOM
SDA	Regional data area, all parameters used in PANDX, INTLD

SGFE2	$\sigma_{\xi 2}$	Meridional stresses for chosen second layer
SGFT2	$\sigma_{\xi\theta 2}$	Shear stresses for chosen second layer
SHTH2	$\sigma_{\theta 2}$	Circumferential stresses for chosen surface
SIG0	σ_0	Reference stress (psi)
SIGFE	σ_ξ	Meridional stresses for inner surface
SIGFT	$\sigma_{\xi\theta}$	Shear stresses for inner surface
SIGTH	σ_θ	Circumferential stresses for inner surface
SINFI		SIN (ANX), used to computed R in cone-cylinder, GEOM
SINNT		SIN (n_θ), used in Fourier summing
SKIP		Path indicator, = 1. for fictitious discontinuity, PANDX
SL1		Path indicator, = 0. for printing when SUM=0.
SL2		Path indicator, = 0. after the first pass when summing
SPN0		Initial opening angle of conics (station 1)
SPNN		Terminal opening angle of conics (station n)
SPRL		Location of spring, SDA (3)
SQ3		Summing coefficient A0 * SIGO/E0
SQ4		Summing coefficient SIGO * H0 ** 3/A0
SQ6		Summing coefficient SIGO * H0
STA		DATLDS, stations at which loads are given in loads tables; DATLYR, combined TSTA and THSTA
STAP		Temporary array stations of apex interpolation in discrete point option
STAW		Temporary array stations of apex interpolation in discrete point option

STAX	Array of meridional stations, PIX
STCØMB	Subroutine to combine thickness and temperature stations
STN	Temperature loads station numbers
STRI	Layer number for second stress print (other = inner surface)
STRIX	STRI in DAL data area
SUM	Indicator, nonzero for multiple Fourier components + = summing, with prints at ENFOR values - = discrete Fourier values, printed each time, no CRT
SUMN	Auxiliary array for summing current Fourier components with previous sums
SUMS	Subroutine which sums Fourier components and prints results
SURB	Arc length in intermediate arc length computation in discrete point option
SURF	Arc length to station location
SURN	Arc length in intermediate arc length computation in conics option

T

T	Temperature change for N summations, SDA (1226)
T2	T for second surface where stresses are computed, SDA (2799)
TAB	Data tables for pressure and temperature loads
TBØT	Loads table for the temperatures on the inner surface
TBØTX	Table location for TBOT values for next Fourier component
TBT	Temperatures for inner surface at STN stations, DATLDS
TEMP	NFE-x-NTH loads array resulting from double interpolation of data

TH		Thicknesses at stations, layers
THETA	θ	Circumferential angles, ten maximum (degrees)
THETX		Circumferential angles for summing loads
THEX		Theta value read from tape, PIX
THK		Thicknesses at combined stations (STA)/layer
THSTA		Station numbers at which thicknesses are given
TIBT		Temperature indicator, inner face (see explanation for DLD data)
TITP		Temperature indicator, outer face (see explanation for DLD data)
TLΦC		Table locations, PFEX, PTHX, PNX, TBOTX, TTOPX
TMP		Temperatures at combined stations (STA)/layer
TMPA1		Temperatures at which thermal expansion coefficients are given, material 1
TMPA2		Temperatures at which thermal expansion coefficients are given, material 2
TMPA3		Temperatures at which thermal expansion coefficients are given, material 3
TMPE1		Temperatures at which Young's moduli are given, material 1
TMPE2		Temperatures at which Young's moduli are given, material 2
TMPE3		Temperatures at which Young's moduli are given, material 3
TSTA		Station numbers at which temperatures are given
TTΦP		Loads table for the temperatures on the outer surface
TTΦPX		Table location for TTOP values for next Fourier component
TTP		Temperatures for outer surface at STN stations, DATLDS

TX		Array used as temporary storage in DATLYR
U		
UK		Spring value in the meridional direction
UP		First derivative of u deflection
USUM		Array which includes all Fourier sums
V		
VAL		Loads values picked up from data tables
VK		Spring value in the circumferential direction
VP		First derivative of the V deflections
VSUM		Array for summing V deflections
W		
WF		Intermediate designation of meridional curvatures in discrete points option for smoothing
WFE	ω_ξ	Nondimensional curvature in the meridional direction
WFEN		WFE at last point, previous region
WFEP		First derivative of WFE
WFP		Intermediate designation of meridional curvatures in the discrete point option
WFW		Intermediate designation of meridional curvatures in the discrete point option
WK		Spring value in the normal direction
WP		First derivative of the W deflection
WSUM		Array for summing W deflections
WT		Intermediate designation of circumferential curvatures in discrete points for smoothing

WTH	ω_θ	Current WTHD value
WTHD		Nondimensional curvature in the circumferential direction
X		
X		Two-dimensional array (Equations 4, 150) used to store the X matrices (Equation 74) at each meridional station/region
X0		4-x-1 matrix for X at the (N -1)st station of the previous region
XD		4-x-4 matrix used at top discontinuity point
XIPT		Discrete X distances, GEOM or arc lengths
XJ		Intermediate X distances for better curve fitting of discrete points
XSI		X distance array used with R's to plot shell shape/region
Y		
YD		4-x-4 matrix used at top discontinuity point
YM1		Young's moduli data, entered for TMPE1 temperatures, first material
YM2		Young's moduli data, entered for TMPE2 temperatures, second material
YM3		Young's moduli data, entered for TMPE3 temperatures, third material
YMX		Constant Young's modulus when there are no temperature loads
Z		
Z		Two dimensional array (Equations 4, 150) of solutions (Equation 73)
Z0		4-x-1 matrix for Z at the (N -1)st station of the previous region

Z1M1	Solution matrix for fictitious point before station 1
ZETA	Intermediate cylindrical coordinates in conics option
ZNP1	Solution matrix for fictitious point after station N
ZTA	Station interpolated cylindrical coordinates in conics option

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