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STUDY OF APOLLO WATER IMPACT

FINAL REPORT

VOLUME 11

USER'S MANUAL FOR UNSYMMETRIC SHELL OF REVOLUTION ANALYSIS

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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.

INDEX FOR FINAL REPORT

"Apollo Water Impact"

Volume No.	Volume Title	Authors
1	Hydrodynamic Analysis of Apollo Water Impact	T. Li and T. Sugimura
2	Dynamic Response of Shells of Revolution During Vertical Impact Into Water - No Interaction	A.P. Cappelli, and J.P.D. Wilkinson
3	Dynamic Response of Shells of Revolution During Vertical Impact Into Water - Hydroelastic Interaction	J.P.D. Wilkinson, A.P. Cappelli, and R.N. Salzman
4	Comparison With Experiments	J.P.D. Wilkinson
5	User's Manual - No Interaction	J.P.D. Wilkinson
6	User's Manual - Interaction	J.P.D. Wilkinson and R.N. Salzman
7	Modification of Shell of Revolution Analysis	A.P. Cappelli and S.C. Furuike
8	Unsymmetric Shell of Revolution Analysis	A.P. Cappelli, T. Nishimoto, P.P. Radkowski and K.E. Pauley
9	Mode Shapes and Natural Frequencies Analysis	A.P. Cappelli
10	User's Manual for Modification of Shell of Revolution Analysis	A.P. Cappelli and S.C. Furuike
11	User's Manual for Unsymmetric Shell of Revolution Analysis	E. Carrión, S.C. Furuike and T. Nishimoto

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Volume 11

User's Manual
For the Unsymmetric Shell of Revolution Computer Programs Static and Dynamic

ABSTRACT

The unsymmetric shell of revolution programs described in this volume were developed as a basic tool in the static and dynamic analysis of shells of revolution having arbitrary distribution of stiffness subjected to arbitrary loads and temperature.

The analytical basis for the two computer programs, static and dynamic, is presented. The analysis is restricted to linear-elastic thin shell theory. The basic equations include the effect of shear distortion. The analysis utilizes a Fourier series technique to separate the circumferential variation. The resulting set of equations are reduced to an algebraic set by the use of finite difference forms for variations of the other variables. These algebraic equations are then solved numerically by a direct matrix elimination procedure.

The computer programs were written in FORTRAN IV. In order to keep input data at a minimum extensive use of call function subroutines have been used. Call functions are subroutines which are coded and compiled by the user. This eliminates the necessity of large tabular inputs.

Solutions obtained from the Dynamic Unsymmetric Shell program are the displacement and rotation time histories. Also included in the output are the histories of internal forces and moments.

The solutions obtained from the Static Unsymmetric Shell program include displacements, rotations, internal force and moment resultants, and stresses. This output is presented in tabular form. The users of these programs should be forewarned that the programs are only a tool and insight must be used in relating results to an actual physical problem.

This volume is intended to supply the information necessary for the use of both the Dynamic Unsymmetric Shell program and the Static Unsymmetric Shell program. Detailed descriptions have been included in this volume to aid the user in performing extensions and modifications of these programs.

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CONTENTS

Section Page

Section Page

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ILLUSTRATIONS

1.0 THEORY

1.1 INTRODUCTION

This section presents the analytical basis of the computer programs. The dynamic response problem is presented and the specialization for the static analysis is made.

The analysis is based on a modified form of the general first order linear shell theory of Sanders. These equations have been modified to include transverse shear distortion, see Appendix 1.13.1 The modified equilibrium equations are extended to include time dependence by D'Alembert's principle. Fourier analysis is used to separate variables in the circumferential direction and a system of finite difference approximations are used to reduce the partial differential equations to an algebraic set. This set is solved by using a direct matrix elimination procedure.

The material presented in this section is an extension and parallels of the work of Sanders[1], Budiansky and Radkowski[2], and Johnson and Greif[3]. The notation used is identical to that of Reference 2 except where noted.

1.2 NOMENCLATURE

Fourier Coefficients

$u_n, v_n, w_n, \phi_{\xi n}, \phi_{\theta n}$ = displacements and rotations

$p_{\xi n}, p_{\theta n}, p_n$ = loads

$t^T_{\xi n}, t^T_{\theta n}, m^T_{\xi n}, m^T_{\theta n}$ = temperature induced force terms

$t^n_\xi, t^n_\theta, t^n_{\xi\theta}, t^n_{\xi\theta}, q^n_\xi$
$q^n_\theta, m^n_\xi, m^n_\theta, m^n_{\xi\theta}$ = force resultants, modified and effective

$b_{mj}, d_{mj}, g_{mj}, g_{13j}$ = stiffnesses

k_{mj}, c_{mj}, m_{mj} = elastic foundation, damping, mass

$$\left.\begin{array}{l}
f_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; f_{5k+5,\,5j+5} \\
g_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; g_{5k+5,\,5j+5} \\
h_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; h_{5k+5,\,5j+5} \\
k_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; k_{5k+5,\,5j+5} \\
\alpha_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; \alpha_{5k+5,\,5j+5} \\
\beta_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; \beta_{5k+5,\,5j+5} \\
p_{5k+1} \cdot \cdot \cdot \cdot \cdot \; p_{5k+5},\, \ell_1^k \cdots \ell_5^k \\
r_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; r_{5k+5,\,5j+5} \\
s_{5k+1,\,5j+1} \cdot \cdot \cdot \cdot \cdot \; s_{5k+5,\,5j+5} \\
a_{5k+1} \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \; a_{5k+5}
\end{array}\right\} = \text{elements of } F,\ G,\ H,\ K,\ \alpha,\ \beta, p, \ell\ R,\ S,\ \text{and } a$$

Coordinates and Constants

ξ, θ, ζ = coordinates

r = normal distance from shell axis

s = meridional shell coordinate

a, h_o, σ_o, E_o = reference constants

$\omega_\theta, \omega_\xi$ = nondimensional curvatures

$u, v, w, \phi_\xi, \phi_\theta$ = displacements and rotations

$\sigma_\xi, \sigma_\theta, \tau_{\xi\theta}, \tau_{\xi\zeta}, \tau_{\theta\zeta}$ = stresses

$$\left.\begin{array}{l}
\epsilon_\xi,\ \epsilon_\theta,\ \epsilon_{\xi\theta},\ k_\xi,\ k_\theta \\
k_{\xi\theta},\ \gamma_{\xi\zeta},\ \gamma_{\theta\zeta}
\end{array}\right\} = \text{strains}$$

$B_i, C_i, D_i, G_i\ K_i, M_i$ = isotropic stiffness functions

E, ν, α = material properties

q_ξ, q_θ, q = loads

T = temperature change

$N_\xi, N_\theta, \overline{N}_{\xi\theta}, M_\xi, M_\theta, \overline{M}_{\xi\theta}, Q_\xi, Q_\theta, \hat{N}_{\xi\theta}, N_\xi^T, N_\theta^T, M_\xi^T, M_\theta^T$ = force resultants, modified, effective, and temperature induced

<u>Matrices</u>

F, G, H, K, α, β, Ω, Λ, R, S = 5K x 5K order

p, ℓ, x = 5K x 1 order

<u>Indices</u>

i, j, n = Dummy

k = k^th Fourier component

1.3 SCOPE AND LIMITATIONS

The shell theory on which these programs are based is restricted to linear, elastic, thin shell theory.

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

(b) Deformations of the shell are small compared to the smallest radius of curvature.

(c) All material points of the shell deform elastically, obeying Hooke's law for transverse isotropic materials.

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

(e) The class of shells considered has a surface of revolution reference surface which is within or in close proximity of the shell walls such that $\int E\zeta d\zeta = 0$.

(f) The parameters of stiffness, e.g., in-plane stiffnesses are permitted to vary in both the meridional and circumferential directions. Implied is that parameters such as thickness, Young's modulus, etc., are permitted to vary in both the meridional and circumferential directions. The stiffness parameter's variation in the circumferential direction is restricted to those with a plane of symmetry.

(g) Arbitrary loads and temperature distributions are permissible. Excluded are problems with thermal distributions such that limitation (e) is not satisfied.

(h) The effects of transverse shear is included.

(i) Instability is not considered.

(j) Distributed mass, elastic foundation, and external damping is included. These distributions have the same symmetry conditions as the stiffness parameters (f).

1.4 SHELL COORDINATE SYSTEM

The geometry of a shell is defined entirely by specifying the form of the reference surface and the thickness of the shell at each point. For convenience, the shell coordinate system and geometrical relations used in Reference 2 will be adopted here. The reference surface is assumed to be a surface of revolution and is selected at a convenient location, within or in proximity to the shell walls. The first fundamental form of the reference surface is defined by

$$d\bar{s}^2 = ds^2 + r^2 d\theta^2 \tag{1.1}$$

where $d\bar{s}$ is a line element on the surface and s and θ denote orthogonal coordinates selected along lines of principal curvature.

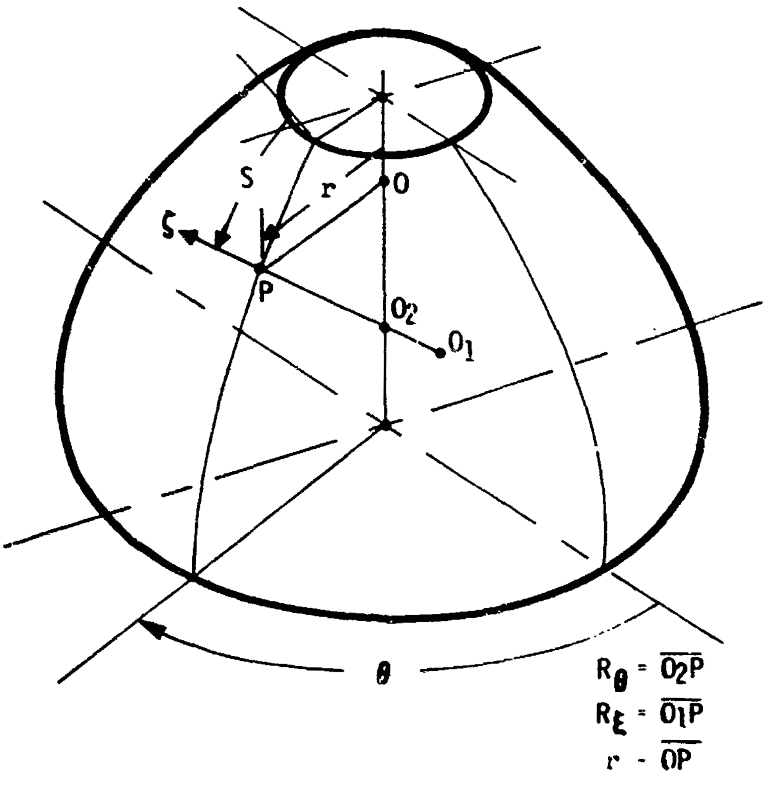


Figure 1.1. Geometry and Coordinates

The generator on the reference surface is defined by r(s) where r is the distance from the axis of revolution. The coordinate s is a measure of the meridional distance along an axisymmetric reference surface, and θ is a circumferential angle, as shown in Figure 1.1. The coordinate, ζ, is selected as a measure of the normal outward distance from the reference surface ($\zeta = 0$). The principal radii of curvature are

$$R_s = -\left[1 - \left(\frac{dr}{ds}\right)^2\right]^{1/2} \Bigg/ \frac{d^2r}{ds^2} \qquad R_\theta = r\left[1 - \left(\frac{dr}{ds}\right)^2\right]^{-1/2} \tag{1.2}$$

Introduce the nondimensional meridional 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

$$\omega_\xi = -(\gamma' + \gamma^2)/\omega_\theta \qquad \omega_\theta = \left[1 - (\rho')^2\right]^{1/2}/\rho \tag{1.3}$$

where

$$\gamma = \rho'/\rho$$

In these equations, and henceforth, $(\ )' = \frac{\partial(\ )}{\partial \xi}$

Finally from the Codazzi relation we obtain

$$\omega_\theta' = \gamma\,(\omega_\xi - \omega_\theta) \tag{1.4}$$

and the relation

$$\frac{\rho''}{\rho} = -\,\omega_\xi \omega_\theta \tag{1.5}$$

1.5 EQUATIONS OF MOTION

The general equilibrium equations for an arbitrary shell based on the first-order linear shell theory of Sanders are given in Reference 1. These equations are modified to include the effect of transverse shear distortion by the procedure suggested by Sanders.* These equilibrium equations are extended to equations of motion by use of D'Alembert's principle. These equations specialized for a shell whose reference surface is a surface of revolution are given as,

---

*See Appendix

$$
\begin{aligned}
&a\left[\frac{\partial \rho}{\partial \xi} N_\xi + \rho \frac{\partial N_\xi}{\partial \xi} + \frac{\partial \overline{N}_{\xi\theta}}{\partial \theta} - \frac{\partial \rho}{\partial \xi} N_\theta\right] + \\
&a\rho\omega_\xi Q_\xi + \frac{1}{2}\left(\omega_\xi - \omega_\theta\right) \frac{\partial \overline{M}_{\xi\theta}}{\partial \theta} + a^2 \rho q_\xi = a^2\rho\left[M \frac{\partial^2 U_\xi}{\partial t^2} + C_\xi \frac{\partial U_\xi}{\partial t} + K_\xi U_\xi\right]
\end{aligned}
\qquad (1.6.1)
$$

$$
\begin{aligned}
&a\left[\frac{\partial N_\theta}{\partial \theta} + 2\frac{\partial \rho}{\partial \xi} \overline{N}_{\xi\theta} + \rho \frac{\partial \overline{N}_{\xi\theta}}{\partial \xi}\right] + a\rho\omega_\theta Q_\theta + \\
&\frac{\rho}{2}\frac{\partial}{\partial \xi}\left[\left(\omega_\theta - \omega_\xi\right) \overline{M}_{\xi\theta}\right] + a^2\rho q_\theta = a^2\rho\left[M \frac{\partial^2 U_\theta}{\partial t^2} + C_\theta \frac{\partial U_\theta}{\partial t} + K_\theta U_\theta\right]
\end{aligned}
\qquad (1.6.2)
$$

$$
\begin{aligned}
&a\left[\frac{\partial \rho}{\partial \xi} Q_\xi + \rho \frac{\partial Q_\xi}{\partial \xi} + \frac{\partial Q_\theta}{\partial \theta} - \right.\\
&\left.\rho\left(\omega_\xi N_\xi + \omega_\theta N_\theta\right)\right] + a^2\rho q_\zeta = a^2\rho\left[M \frac{\partial^2 W}{\partial t^2} + C_\zeta \frac{\partial W}{\partial t} + K_\zeta W\right]
\end{aligned}
\qquad (1.6.3)
$$

$$
\begin{aligned}
&\frac{\partial \rho}{\partial \xi} M_\xi + \rho \frac{\partial M_\xi}{\partial \xi} + \\
&\frac{\partial \overline{M}_{\xi\theta}}{\partial \theta} - \frac{\partial \rho}{\partial \xi} M_\theta - a\rho Q_\xi = a\rho\left[M^* \frac{\partial^2 \Phi_\xi}{\partial t^2} + C^*_\xi \frac{\partial \Phi_\xi}{\partial t} + K^*_\xi \Phi_\xi\right]
\end{aligned}
\qquad (1.6.4)
$$

$$
\begin{aligned}
&\frac{\partial M_\theta}{\partial \theta} + 2\frac{\partial \rho}{\partial \xi} \overline{M}_{\xi\theta} + \\
&\rho \frac{\partial M_{\xi\theta}}{\partial \xi} - a\rho Q_\theta = a\rho\left[M^*_\theta \frac{\partial^2 \Phi_\theta}{\partial t} + C^*_\theta \frac{\partial \Phi_\theta}{\partial t} + K^*_\theta \Phi_\theta\right]
\end{aligned}
\qquad (1.6.5)
$$

where

$M(\xi, \theta) = \rho(\xi, \theta)\, h(\xi, \theta)$ (mass/unit area of shell)

$M(\xi, \theta)^* = \dfrac{\rho(\xi, \theta)\, h^3(\xi, \theta)}{12}$ (mass moment/unit area of shell)

$C_{(\ )}(\xi, \theta)$ = external damping coefficient

$K_{(\ )}(\xi, \theta)$ = spring constants

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

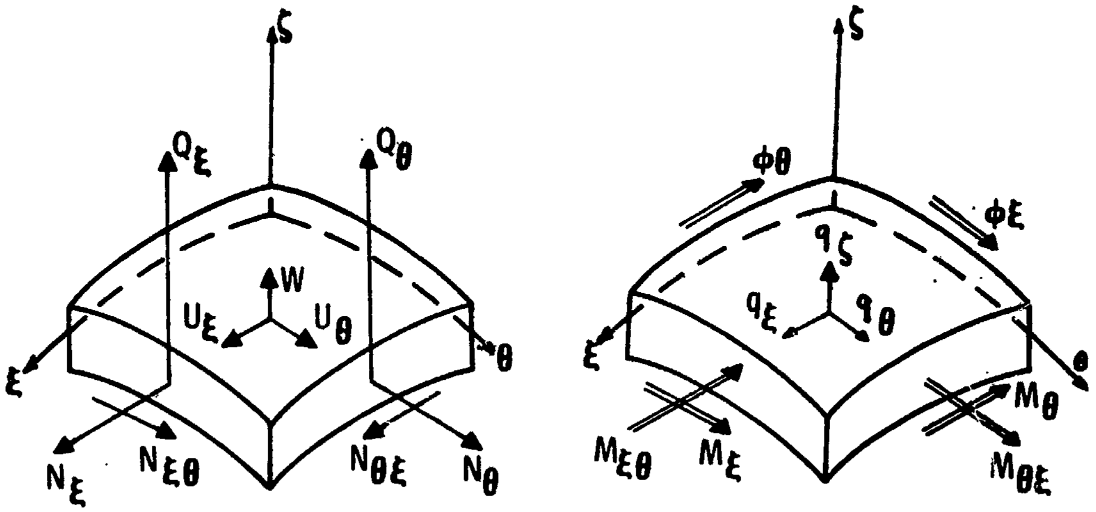


Figure 1-2. Sign Convention and Coordinates, Moments, Forces, Loads, Displacements, and Rotations

In the Sanders' first-order theory the inplane shearing forces $N_{\xi\theta}$ and $N_{\theta\xi}$ as well as twisting moments $M_{\xi\theta}$ and $M_{\theta\xi}$ are not handled separately, but instead are combined to form modified variables

$$\overline{N}_{\xi\theta} = \frac{1}{2}(N_{\xi\theta} + N_{\theta\xi}) \tag{1.7}$$

$$\overline{M}_{\xi\theta} = \frac{1}{2}(M_{\xi\theta} + M_{\theta\xi}) \tag{1.8}$$

and

$$\overline{k}_{\xi\theta} = \frac{1}{2}(k_{\xi\theta} + k_{\theta\xi}) \tag{1.9}$$

It is necessary when including the effects of transverse shear distortion to consider five equilibrium equations. Recall in Reference 2 that when shear deformation is neglected the shear forces are eliminated and resulting equilibrium equations are reduced to the consideration of three equations. The neglecting of transverse shear strains implies that normals to middle surface of the shell remain normal after deformation. The degree of error introduced by this assumption naturally depends on the magnitude of transverse shearing forces and shear rigidity of the shell. For discontinuous loads and shells having low shear rigidity, shear deformations may be comparable to bending and axial deformations and cannot be ignored.

1.6 FORMULATION INTO SOLUTION VARIABLES

The equations of motion are now expressed in terms of the solution variables, displacements and rotations.

The force and moment expressions in the equations of motion are determined by evaluating the following integrals through the thickness

$$
\begin{aligned}
N_\xi &= \int \sigma_\xi d\zeta & M_\xi &= \int \sigma_\xi \zeta d\zeta \\
N_\theta &= \int \sigma_\theta d\zeta & M_\theta &= \int \sigma_\theta \zeta d\zeta \\
\overline{N}_{\xi\theta} &= \int \tau_{\xi\theta} d\zeta & \overline{M}_{\xi\theta} & \int \tau_{\xi\theta} \zeta d\zeta \\
Q_\xi &= \int \tau_{\xi\zeta} d\zeta & Q_\theta &= \int \tau_{\theta\zeta} d\zeta
\end{aligned}
\qquad (1.10)
$$

where in the above integrals we have neglected terms of order ζ/R, R is the minimum radius of curvature. The stresses used above are defined as:

$\sigma_\xi, \sigma_\theta$	are normal stresses, acting on the faces
$\tau_{\xi\theta}$	is an in-plane shear stress acting parallel to the reference surface
$\tau_{\xi\zeta}, \tau_{\theta\zeta}$	are transverse shear stresses acting normal to the reference surface

By assuming that plane sections before remain plane after deformation, the strains at a distance ζ from the reference surface can be expressed in terms of the reference surface strains as follows:

$$
\begin{aligned}
\epsilon_\xi(\zeta) &= \epsilon_\xi + \zeta k_\xi \\
\epsilon_\theta(\zeta) &= \epsilon_\theta + \zeta k_\theta \\
\epsilon_{\xi\theta}(\zeta) &= \epsilon_{\xi\theta} + \zeta \bar{k}_{\xi\theta}
\end{aligned}
\qquad (1.11)
$$

where ϵ_ξ, ϵ_θ and $\epsilon_{\xi\theta}$ are the strains of the reference surface and $\epsilon_{\xi\theta}(\zeta)$ is one-half the usual engineering strain.

The stress-strain-temperature relations for an isotropic material are

$$\begin{aligned}
\sigma_\xi &= \frac{E}{1-\nu^2}\Big|\epsilon_\xi + \nu\epsilon_\theta + \zeta\,(k_\xi + \nu k_\theta) - \alpha\,(1+\nu)\,T\Big| \\
\sigma_\theta &= \frac{E}{1-\nu^2}\Big|\epsilon_\theta + \nu\epsilon_\xi + \zeta\,(k_\theta + \nu k_\xi) - \alpha\,(1+\nu)\,T\Big| \\
\tau_{\xi\theta} &= G\,(\epsilon_{\xi\theta} + \zeta\bar{k}_{\xi\theta}) \\
\tau_{\xi\zeta} &= G\,(\gamma_{\xi\zeta}) \\
\tau_{\theta\zeta} &= G\,(\gamma_{\theta\zeta})
\end{aligned} \tag{1.12}$$

where

$$G = \frac{E}{2(1+\nu)}$$

Substituting these equations into Eqs. 1.10 and employing appropriate integrations through the thickness yield the following stress/resultants-strain relationships.

$$\begin{aligned}
N_\xi &= B_1\epsilon_\xi + B_3\epsilon_\theta + C_1k_\xi + C_3k_\theta - N_\xi^T \\
N_\theta &= B_3\epsilon_\xi + B_2\epsilon_\theta + C_3k_\xi + C_2k_\theta - N_\theta^T \\
\overline{N}_{\xi\theta} &= G_1\epsilon_{\xi\theta} + G_{12}k_{\xi\theta} \\
Q_\xi &= G_2\gamma_{\xi\zeta} \\
M_\xi &= C_1\epsilon_\xi + C_3\epsilon_\theta + D_1k_\xi + D_3k_\theta - M_\xi^T \\
M_\theta &= C_3\epsilon_\xi + C_2\epsilon_\theta + D_3k_\xi + D_2k_\theta - M_\theta^T \\
\overline{M}_{\xi\theta} &= G_{12}\epsilon_{\xi\theta} + G_{13}k_{\xi\theta} \\
Q_\theta &= G_3\gamma_{\theta\zeta}
\end{aligned} \tag{1.13}$$

where in the above equations the shell stiffnesses are given by

$$B_1 = B_2 = \int \frac{E}{1 - \nu^2} d\zeta, \; B_3 = \int \frac{\nu E}{1 - \nu^2} d\zeta, \; C_1 = C_2 = \int \frac{E\zeta}{1 - \nu^2} d\zeta, \; C_3 = \int \frac{\nu E\zeta}{1 - \nu^2} d\zeta$$

$$D_1 = D_2 = \int \frac{E}{1 - \nu^2} \zeta^2 d\zeta, \; D_3 = \int \frac{\nu E \zeta^2}{1 - \nu^2} d\zeta$$

$$G_1 = G_2 = G_3 = \int G d\zeta \tag{1.14}$$

$$G_{12} = \int G\zeta d\zeta$$

$$G_{13} = \int G\zeta^2 d\zeta$$

and thermal loads are

$$N_\xi^T = N_\theta^T = \int \frac{\alpha\,(1 + \nu)}{1 - \nu^2} ET d\zeta$$

$$M_\xi^T = M_\theta^T = \int \frac{\alpha\,(1 + \nu)}{1 - \nu^2} ET\zeta d\zeta \tag{1.15}$$

For the case of discontinuous material properties through the thickness the integration is taken piece-wise through the thickness. An additional assumption of constant Poisson's ratios through the thickness is made. Therefore the isotropic nature of the layers are retained in the stiffness parameters. The shell stiffness and thermal loads take the form,

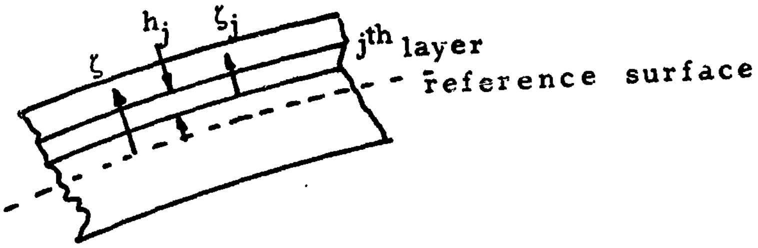
$$B_1 = B_2 = \frac{B_3}{\nu} = \frac{1}{1 - \nu^2} \int E d\zeta, \; D_1 = D_2 = \frac{D_3}{\nu} = \frac{1}{1 - \nu^2} \int E\zeta^2 d\zeta$$

$$C_1 = C_2 = \frac{C_3}{\nu} = \frac{1}{1 - \nu^2} \int E\zeta d\zeta, \; G_1 = G_2 = G_3 = B_1 \frac{(1 - \nu)}{2} \tag{1.16}$$

$$G_{12} = C_1 \frac{(1 - \nu)}{2}, G_{13} = D_1 \frac{(1 - \nu)}{2}$$

It follows that because of the reference surface choice, namely that the condition $\int E\zeta d\zeta = 0$ is satisfied, the integration takes the form

$$A = \int F_{(\zeta)} d\zeta = \sum_{j} \int_{0}^{h_j} F_j\,(\zeta_j)\, d\zeta_j \tag{1.17}$$



The reference surface strains and bending distortion terms may be defined in terms of displacements and rotations by the following expressions. The membrane strains of the reference surface are given by

$$\begin{aligned} \epsilon_\xi &= \frac{1}{a}\left[\frac{\partial U_\xi}{\partial \xi} + \omega_\xi W\right] \\ \epsilon_\theta &= \frac{1}{a}\left[\frac{1}{\rho}\frac{\partial U_\theta}{\partial \theta} + \gamma U_\xi + \omega_\theta W\right] \\ \epsilon_{\xi\theta} &= \frac{1}{2a}\left[\frac{1}{\rho}\frac{\partial U_\xi}{\partial \theta} + \frac{\partial U_\theta}{\partial \xi} - \gamma U_\theta\right] \end{aligned} \tag{1.18}$$

where U, V, W are displacements in the ξ, θ and ζ directions respectively. Transverse shear strains are given by

$$\begin{aligned} \gamma_{\xi\zeta} &= \Phi_\xi - \frac{1}{a}\left[\omega_\xi U_\xi - \frac{\partial W}{\partial \xi}\right] \\ \gamma_{\theta\zeta} &= \Phi_\theta - \frac{1}{a}\left[\omega_\theta U_\theta - \frac{1}{\rho}\frac{\partial W}{\partial \theta}\right] \end{aligned} \tag{1.19}$$

where Φ_ξ, Φ_θ are rotations.

The bending distortion terms are given by

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

$$k_\theta = \frac{1}{a}\left[\frac{1}{\rho}\frac{\partial \Phi_\theta}{\partial \theta} + \gamma \Phi_\xi\right] \qquad (1.20)$$

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

Substituting equations (1. 18, 1. 19, 1. 20) into equation 1. 13 the force terms in the equations of motion can be expressed in terms of the displacements

$$N_\xi = \frac{1}{a}\left\{B_1 \frac{\partial U_\xi}{\partial \xi} + B_3 \gamma U_\xi + B_3\left(\frac{1}{\rho}\right)\frac{\partial U_\theta}{\partial \theta} + (B_1 \omega_\xi + B_2 \omega_\theta) W\right\} - N^T$$

$$N_\theta = \frac{1}{a}\left\{B_3 \frac{\partial U_\xi}{\partial \xi} + B_2 \gamma U_\xi + B_2\left(\frac{1}{\rho}\right)\frac{\partial U_\theta}{\partial \theta} + (B_3 \omega_\xi + B_2 \omega_\theta) W\right\} - N^T$$

$$N_{\xi\theta} = \frac{1}{2a}\left\{\frac{1}{\rho} G_1 \frac{\partial U_\xi}{\partial \theta} + G_1 \frac{\partial U_\theta}{\partial \xi} - \gamma G_1 U_\theta\right\}$$

$$Q_\xi = G_2\left\{-\frac{1}{a}\omega_\xi U_\xi + \frac{1}{a}\frac{\partial W}{\partial \xi} + \Phi_\xi\right\}$$

$$M_\xi = \frac{1}{a}\left\{D_1 \frac{\partial \Phi_\xi}{\partial \xi} + D_3 \gamma \Phi_\xi + D_3 \frac{1}{\rho}\frac{\partial \Phi_\theta}{\partial \theta}\right\} - M^T \qquad (1.21)$$

$$M_\theta = \frac{1}{a}\left\{D_3 \frac{\partial \Phi_\xi}{\partial \xi} + D_2 \gamma \Phi_\xi + D_2 \frac{1}{\rho}\frac{\partial \Phi_\theta}{\partial \theta}\right\} - M^T$$

$$\overline{M}_{\xi\theta} = \frac{1}{2a}\left\{\frac{1}{2a} G_{13} (\omega_\xi - \omega_\theta)\left(\frac{1}{\rho}\frac{\partial U_\xi}{\partial \theta} - \frac{\partial U_\theta}{\partial \xi} - \gamma U_\theta\right) + G_{13}\left(\frac{1}{\rho}\frac{\partial \Phi_\xi}{\partial \theta} + \frac{\partial \Phi_\theta}{\partial \xi} - \gamma \Phi_0\right)\right\}$$

$$Q_\theta = G_3\left\{-\frac{1}{a}\omega_\theta U_\theta + \frac{1}{a\rho}\frac{\partial W}{\partial \theta} + \Phi_\theta\right\}$$

By employing the relations, equations 1. 21 the equations of motion can be expressed in terms of the dependent variables, displacements and rotations.

1.7 CIRCUMFERENTIAL VARIABLE SEPARATION

The analysis utilizes a Fourier approach which will permit separation of variables and yield a more tractable set of shell equations. The procedure involves expanding of the pertinent variables in Fourier series with appropriate normalization to provide nondimensional Fourier coefficients of roughly comparable magnitudes for different variables. Letting σ_o, E_o, h_o be a reference stress level, Young's modulus, and thickness, respectively, solutions for the field equations are sought in the form

$$U_\xi = \frac{a\sigma_o}{E_o} \sum_{n=0}^{\infty} u_n\,(\xi,\ t)\ \mathrm{Cos}\ n\theta$$

$$U_\theta = \frac{a\sigma_o}{E_o} \sum_{n=1}^{\infty} v_n\,(\xi,\ t)\ \mathrm{Sin}\ n\theta$$

$$W = \frac{a\sigma_o}{E_o} \sum_{n=0}^{\infty} w_n\,(\xi,\ t)\ \mathrm{Cos}\ n\theta \tag{1.22}$$

$$\Phi_\xi = \frac{\sigma_o}{E_o} \sum_{n=0}^{\infty} \phi_{\xi n}\,(\xi,\ t)\ \mathrm{Cos}\ n\theta$$

$$\Phi_\theta = \frac{\sigma_o}{E_o} \sum_{n=1}^{\infty} \phi_{\theta n}\,(\xi,\ t)\ \mathrm{Sin}\ n\theta$$

These Fourier expansions are consistent with loadings of the form

$$q_\xi = \frac{\sigma_o h_o}{a} \sum_{n=0}^{\infty} p_{\xi n}\,(\xi,\ t)\ \mathrm{Cos}\ n\theta$$

$$q_\theta = \frac{\sigma_o h_o}{a} \sum_{n=1}^{\infty} p_{\theta n}\,(\xi,\ t)\ \mathrm{Sin}\ n\theta \tag{1.23}$$

$$q_\zeta = \frac{\sigma_o h_o}{a} \sum_{n=0}^{\infty} p_{\zeta n}\,(\xi,\ t)\ \mathrm{Cos}\ n\theta$$

The above Fourier expansions are not the most general form. The expansions q_ζ, q_ξ are symmetrical expansions about $\theta = 0$. For full generality, they must be augmented by additional sine series expansions. The form q_θ in turn would be supplemented by cosine series. Consistently, the series expansions for displacements and rotations must be augmented for the general case.

Expansions for the temperature distributions may be described in a similar manner; however, since the thermal coefficients and Young's modulus can vary in the circumferential direction, it will be more convenient to expand the thermal load in Fourier series as follows

$$
\begin{aligned}
N^T &= \sigma_o h_o \sum_{n=0}^{\infty} t_n^T \operatorname{Cos} n\theta \\
M^T &= \frac{\sigma_o h_o^3}{a} \sum_{n=0}^{\infty} m_n^T \operatorname{Cos} n\theta
\end{aligned}
\tag{1.24}
$$

Where the Fourier components t_n^T and m_n^T are given by

$$t_n^T = \frac{2}{\pi} \int_o^{\pi} \frac{N^T}{\sigma_o h_o} \operatorname{Cos} n\theta \, d\theta$$

$$m_n^T = \frac{2}{\pi} \int_o^{\pi} \frac{aM^T}{\sigma_o h_o^3} \operatorname{Cos} n\theta \, d\theta$$

Since the stiffness mass, external damping and elastic foundation parameters are variable in the circumferential directions, these will also be expanded in a Fourier series. For example, the expansion for the extensional stiffness parameter is of the form

$$B = \sum_{j=0}^{\infty} b_j \operatorname{Cos} j\theta + \sum_{j=1}^{\infty} b_j \operatorname{Sin} j\theta \tag{1.25}$$

In many problems, there exists a plane of symmetry with respect to planform geometry. See Figure 1-3.

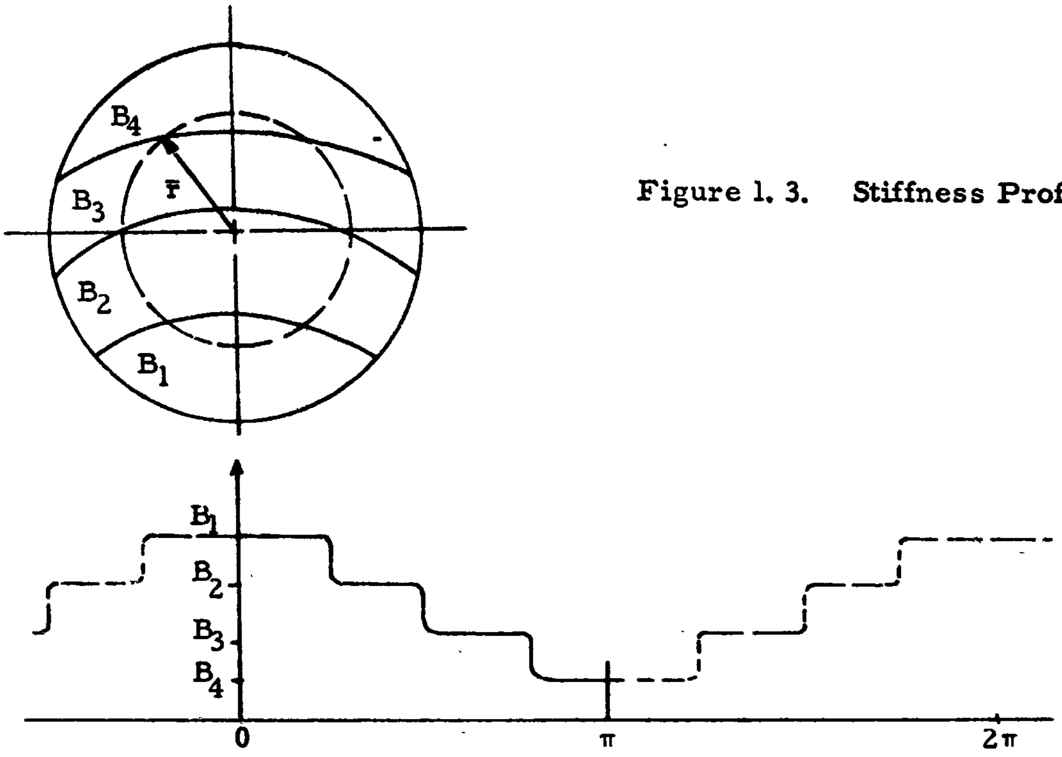


Figure 1. 3. **Stiffness Profile**

A plane of symmetry is assumed here. The coefficients of B, viz., b_j are found by integrations of the form

$$b_j = \frac{2}{\pi} \int_o^{\pi} B\ (\xi,\ \theta)\ \mathrm{Cos}\ j\theta d\theta \tag{1.26}$$

The Fourier expansions of the shell stiffness parameters (Eqs. 1.14), consistent with previous formulation are given by

$$B_m = E_o h_o \sum_{j=0}^{\infty} b_{mj}\ (\xi)\ \mathrm{Cos}\ j\theta \qquad \text{Inplane Stiffness}$$

$$D_m = E_o h_o^3 \sum_{j=0}^{\infty} d_{mj}\ (\xi)\ \mathrm{Cos}\ j\theta \qquad \text{Bending Stiffness} \tag{1.27}$$

$$C_m = \sum_{j=0}^{\infty} c_{mj}\ (\xi)\ \mathrm{Cos}\ j\theta \qquad \text{External Damping}$$

$$K_m = \sum_{j=0}^{\infty} k_{mj}\,(\xi)\,\mathrm{Cos}\; j\theta \qquad \text{Elastic Foundation}$$

$$M_m = \sum_{j=0}^{\infty} m_{mj}\,(\xi)\,\mathrm{Cos}\; j\theta \qquad \text{Mass Property} \tag{1.27}$$

Substitution of the displacement and rotation series expansions (Eqs. 1.22) and the above stiffness expansions into Eqs. (1.21) and employing the proper trigonometric identities yields the following series expressions relating forces (moments) in terms of the Fourier coefficients of the displacement variables and stiffness parameters:

$$N_\xi = \sigma_o h_o \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} \left\{ B_1^{kj} \left(\frac{\partial u_j}{\partial \xi} + \omega_\xi w_j \right) + B_3^{kj} \left(\gamma u_j + \frac{k}{\rho} v_j + \omega_\theta w_j \right) \right\} - t_k^T \right] \mathrm{Cos}\; k\theta$$

$$N_\theta = \sigma_o h_o \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} \left\{ B_3^{kj} \left(\frac{\partial u_j}{\partial \xi} + \omega_\xi w_j \right) + B_2^{kj} \left(\gamma u_j + \frac{k}{\rho} v_j + \omega_\theta w_j \right) \right\} - t_k^T \right] \mathrm{Cos}\; k\theta$$

$$\overline{N}_{\xi\theta} = \sigma_o h_o \sum_{k=1}^{\infty} \left[\sum_{j=0}^{\infty} \frac{G_1^{kj}}{2} \left(\frac{\partial v_j}{\partial \xi} - \frac{k}{\rho} u_j - \gamma v_j \right) \right] \mathrm{Sin}\; k\theta \tag{1.28}$$

$$Q_\xi = \sigma_o h_o \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} G_2^{kj} \left(-\omega_\xi u_j + \frac{\partial w_j}{\partial \xi} + \phi_{\xi j} \right) \right] \mathrm{Cos}\; k\theta$$

$$M_\xi = \frac{\sigma_o h_o^3}{a} \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} \left\{ D_1^{kj} \frac{\partial \phi_{\xi j}}{\partial \xi} + D_3^{kj} \left(\gamma \phi_{\xi j} + \frac{k}{\rho} \phi_{\theta j} \right) \right\} - m^T \right] \mathrm{Cos}\; k\theta$$

$$M_\theta = \frac{\sigma_o h_o^3}{a} \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} \left\{ D_3^{kj} \frac{\partial \phi_{\xi j}}{\partial \xi} + D_2^{kj} \left(\gamma \phi_{\xi j} + \frac{k}{\rho} \phi_{\theta j} \right) \right\} - m^T \right] \mathrm{Cos}\; k\theta$$

$$\overline{M}_{\xi\theta} = \frac{\sigma_o h_o^3}{a} \sum_{k=1}^{\infty} \left[\sum_{j=0}^{\infty} \frac{G_{13}^{kj}}{2} \left(- \frac{k}{\rho} \phi_{\xi_j} + \frac{\partial \phi_{\theta j}}{\partial \xi} - \gamma \phi_{\theta_j} + \frac{1}{2} (\omega_\xi - \omega_\theta) \right) \right.$$

$$\left. \left(- \frac{k}{\rho} u_j - \frac{\partial v_j}{\partial \xi} - \gamma_{v_j} \right) \right] \text{Sin } k\theta \qquad (1.28)$$

$$Q_\theta = \sigma_o h_o \sum_{n=1}^{\infty} \left[\sum_{j=0}^{\infty} \left\{ G_3^{kj} \left(- \omega_\theta v_j - \frac{k}{\rho} w_j + \phi_{\theta j} \right) \right\} \right] \text{Sin } k\theta$$

The translational inertial force terms are expressed as

$$M_\xi \ddot{U} = \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} M_1^{kj} \ddot{u}_j \right] \text{Cos } k\theta$$

$$M_\theta \ddot{V} = \sum_{k=1}^{\infty} \left[\sum_{j=0}^{\infty} M_2^{kj} \ddot{v}_j \right] \text{Sin } k\theta \qquad (1.29)$$

$$M_\zeta \ddot{W} = \sum_{k=0}^{\infty} \left[\sum_{j=0}^{\infty} M_3^{kj} \ddot{w}_j \right] \text{Cos } k\theta$$

The translational damping force is expressible as

$$C_{D_\xi} \dot{U} = \sum_{k=0}^{\infty} \left(\sum_{j=0}^{\infty} C_1^{kj} \dot{u}_j \right) \text{Cos } k\theta$$

$$C_{D_\theta} \dot{V} = \sum_{k=1}^{\infty} \left(\sum_{j=0}^{\infty} C_2^{kj} \dot{v}_j \right) \text{Sin } k\theta \qquad (1.30)$$

$$C_{D_\zeta} \dot{W} = \sum_{k=0}^{\infty} \left(\sum_{j=0}^{\infty} C_3^{kj} \dot{w}_j \right) \text{Cos } k\theta$$

The translational elastic foundation force is expressible as

$$K_\xi U = \sum_{k=0}^{\infty} \left(\sum_{j=0}^{\infty} k_1^{kj} u_j \right) \text{Cos} \, k\theta$$

$$K_\theta V = \sum_{k=1}^{\infty} \left(\sum_{j=0}^{\infty} k_2^{kj} v_j \right) \text{Sin} \, k\theta \qquad (1.31)$$

$$K_\zeta W = \sum_{k=0}^{\infty} \left(\sum_{j=0}^{\infty} k_3^{kj} w_j \right) \text{Cos} \, k\theta$$

The stiffness recursion relationships above are described in the form

$$A^{kj} = \frac{1}{2} \left\{ a_{(k+j)} + \left[1 - \delta^2 (j - n) + \delta (k) \right] a_{|k-j|} \right\}$$

$$\bar{A}^{kj} = \frac{1}{2} \left\{ - \bar{a}_{(k+j)} + \left[1 - \delta^2 (j - k) + \delta (k) \right] \bar{a}_{|k-j|} \right| \qquad (1.32)$$

where the specific coefficients of interest (dropping k_j superscript) are given by

$$A = \left| B_1, \; B_2, \; B_3, \; D_1, \; D_2, \; D_3, \; g_2, \; M_1, \; M_3, \; C_1, \; C_3, \; K_1, \; K_3 \right|$$

$$a = \left| b_1, \; b_2, \; b_3, \; d_1, \; d_2, \; d_3, \; g_2, \; m_1, \; m_3, \; c_1, \; c_3, \; k_1, \; k_3 \right|$$

and

$$\bar{A} = \left| G_1, \; G_3, \; G_{13}, \; M_2, \; C_2, \; K_2 \right|$$

$$\bar{a} = \left| g_1, \; g_3, \; g_{13}, \; m_2, \; c_2, \; k_2 \right|$$

In the above expressions $\delta(m)$ is defined as

$$\delta(m) = \begin{cases} -1, & m < 0 \\ 0, & m = 0 \\ +1, & m > 0 \end{cases}$$

(*See Appendix 1.2 (multiplication of series expressions) for a more detailed description of A^{kj} and $\bar{A}^{kj}$.)

Substitution of the stress resultant expressions and dynamic force resultants (Eqs. 1.28 - 1.31) into the shell equilibrium equations (Eqs. 1.6) yields five finite series expressions in the circumferential coordinate relating the Fourier coefficients u_j, v_j, w_j, $\phi_{\xi j}$ and $\phi_{\theta j}$ of the displacement and rotation variables. For practical considerations we truncate the series solution of the dependent variables to K terms in the Fourier component. Employing the appropriate orthogonality relationships of Fourier series to these equilibrium expressions yields a system of 5K ordinary differential equations relating the 5K unknown Fourier coefficients. These equations are presented in a form amenable for computer programming and are given as follows:

$$\begin{aligned}
\sum_{j=0}^{K-1} \Big[& f_{5k+\ell,\,5j+1}\, u_j'' + \\
& f_{5k+\ell,\,5j+2}\, v_j'' + f_{5k+\ell,\,5j+3}\, w_j'' + \\
& f_{5k+\ell,\,5j+4}\, \phi_{\xi j}'' + f_{5k+\ell,\,5j+5}\, \phi_{\theta j}'' + \\
& g_{5k+\ell,\,5j+1}\, u_j' + \ldots + g_{5k+\ell,\,5j+5}\, \phi_{\theta_j} + \\
& h_{5k+\ell,\,5j+1}\, u_j + \ldots + h_{5k+\ell,\,5j+5}\, \phi_{\theta j} + \qquad\qquad (1.33) \\
& k_{5k+\ell,\,5j+1}\, u_j + \ldots + k_{5k+\ell,\,5j+1}\, \phi_{\theta j} = \alpha_{5k+\ell,\,5j+1}\, \ddot{u}_j + \ldots + \\
& \qquad \alpha_{5k+\ell,\,5j+5}\, \ddot{\phi}_{\theta_j} + \\
& \qquad \beta_{5k+\ell,\,5j+1}\, \dot{u}_j + \ldots + \\
& \qquad \beta_{5k+\ell,\,5j+5}\, \dot{\phi}_{\theta_j} + P_{5k+\ell}
\end{aligned}$$

where

$\ell = 1, 2, 3, 4, 5$

$k, j = 0, \ldots, K - 1$

where the f, g, h, k, α and β coefficients are described in Appendix 1-B. (It should be noted that the form of the above equations is more complicated than was obtained in Reference 2 for analysis of shells of revolution. This complexity arises from the fact that the equilibrium equations cannot be decoupled for each Fourier component of displacement variables for the case of unsymmetric shell.)

The above equation can be conveniently written in matrix form as follows:

$$Fz'' + Gz' + (H + K)\,z = \alpha\ddot{z} + \beta\dot{z} + p \qquad (1.34)$$

where F, G, H, K, α, β are square arrays and z, p are column arrays. These arrays are defined as,

$$F = \begin{bmatrix} f_{11}, & f_{12} & \cdot & \cdot & f_{1,5k} \\ f_{21} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ f_{5k,1} & \cdot & \cdot & \cdot & f_{5k,5k} \end{bmatrix} \qquad G = \begin{bmatrix} g_{11} & g_{12} & \cdot & \cdot & \cdot \\ g_{21} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot \end{bmatrix}$$

$$H = \begin{bmatrix} h_{11}, & h_{12} & \cdot & \cdot & \cdot \\ h_{21} & \cdot\cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \end{bmatrix} \qquad K = \begin{bmatrix} k_{11}, & k_{12} & \cdot & \cdot & \cdot \\ k_{21} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ k_{5k,1} & \cdot & \cdot & \cdot & \cdot \end{bmatrix}$$

$$\alpha = \begin{bmatrix} \alpha_{11}, & \alpha_{12} & \cdot & \cdot & \cdot \\ \alpha_{21} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \end{bmatrix}, \qquad \beta = \begin{bmatrix} \beta_{11}, & \beta_{12} & \cdot & \cdot & \cdot \\ \beta_{21} & \cdot & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot \\ \cdot & & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \end{bmatrix}$$

$$z = \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ \cdot \\ z_k \end{bmatrix} \qquad z_i = \begin{bmatrix} u_i \\ v_i \\ w_i \\ \phi_{\xi_i} \\ \phi_{\theta_i} \end{bmatrix} \qquad p = \begin{bmatrix} p_1 \\ p_2 \\ \cdot \\ \cdot \\ p_k \end{bmatrix} \qquad p_i = \begin{bmatrix} p_1^i \\ p_2^i \\ p_3^i \\ p_4^i \\ p_5^i \end{bmatrix}$$

The elements of the F, G and H, K, α, β, and p matrices are given in Appendix 1.13.1 and are presented there in a format which is designed to ease computer programming. The coefficients of P are the Fourier components of the applied external load and are known quantities for a specific loading case.

The more general case of shells having arbitrary distribution of stiffness, loads, damping, and elastic foundation can be considered in the same manner as the case of plane of symmetry of stiffness and loads. In this case the total Fourier series representation of all the variables, displacements, rotations, stiffness and loads, must be carried in the analysis. The analysis will follow the same format of the special case formulated previously.

Boundary Conditions

Consistent with Sanders' equilibrium equations, the boundary conditions for the specification of the forces or displacements, or constraint between them are described below. On the edge where ξ = constant (i.e., $\xi = 0$, and $\xi = \bar{s}$)

$$\begin{aligned} &N_\xi \text{ or } U_\xi \\ &\hat{N}_{\xi\theta} \text{ or } U_\theta \\ &Q_\xi \text{ or } W \\ &M_\xi \text{ or } \Phi_\xi \\ &\overline{M}_{\xi\theta} \text{ or } \Phi_\theta \end{aligned} \tag{1.35}$$

where

$$\hat{N}_{\xi\theta} = \bar{N}_{\xi\theta} + \frac{1}{2a}(\omega_0 - \omega_\xi)\,\overline{M}_{\xi\theta}$$

These conditions can be expressed in matrix form by,

$$\bar{\Omega}\bar{y} + \bar{\Lambda}\bar{z} = \bar{\ell} \tag{1.36}$$

where $\bar{y}$, $\bar{\ell}$, $\bar{z}$ are column matrices and $\bar{\Omega}$, $\bar{\Lambda}$ are appropriate diagonal matrices

$$\bar{y} = \begin{bmatrix} N_\xi \\ \hat{N}_{\xi\theta} \\ Q_\xi \\ M_\xi \\ M_{\xi\theta} \end{bmatrix} \qquad \bar{z} = \begin{bmatrix} U_\xi \\ U_\theta \\ W \\ \Phi_\xi \\ \Phi_\theta \end{bmatrix} \qquad \bar{\ell} = \begin{bmatrix} \ell_1 \\ \ell_2 \\ \ell_3 \\ \ell_4 \\ \ell_5 \end{bmatrix}$$

$$\bar{\Omega} = \begin{bmatrix} \omega_1 & & & & \\ & \omega_2 & & 0 & \\ & & \omega_3 & & \\ & 0 & & \omega_4 & \\ & & & & \omega_5 \end{bmatrix} \qquad \bar{\Lambda} = \begin{bmatrix} \lambda_1 & & & & \\ & \lambda_2 & & 0 & \\ & & \lambda_3 & & \\ & 0 & & \lambda_4 & \\ & & & & \lambda_5 \end{bmatrix}$$

The logic which connects $\bar{\Omega}$, $\bar{\Lambda}$, $\bar{\ell}$ and the conditions desired are given in the following table:

Matrix Elements

Condition at Boundary	ω_i	λ_i	ℓ_i	
Displacement Prescribed	0	1	C_1	C_1 = value of displacement
Force Prescribed	1	0	C_2	C_2 = value of force
Constraint Condition	1	C_3	0	C_3 = constant relating force and displacement

For example, is Φ_ξ is given as a boundary condition then $\lambda_4 = 1$, $\omega_4 = 0$ and ℓ_4 is the prescribed value of Φ_ξ. Note C_i is nondimensionalized with the appropriate reference constants.

It will be convenient to expand forces and moments in Fourier series in manner consistent with the previous developments. Letting

$$\begin{aligned} N_\xi &= \sum t_\xi^n \text{ Cos } n\theta \\ \hat{N}_{\xi\theta} &= \sum \hat{t}_{\xi\theta}^n \text{ Sin } n\theta \\ Q_\xi &= \sum q_\xi^n \text{ Cos } n\theta \\ M_\xi &= \sum m_\xi^n \text{ Cos } n\theta \\ \overline{M}_{\xi\theta} &= \sum m_{\xi\theta}^n \text{ Sin } n\theta \end{aligned} \tag{1.37}$$

and

$$\begin{aligned} \ell_1 &= \sum \ell_1^n \text{ Cos } n\theta \\ \ell_2 &= \sum \ell_2^n \text{ Sin } n\theta \\ \ell_3 &= \sum \ell_3^n \text{ Cos } n\theta \\ \ell_4 &= \sum \ell_4^n \text{ Cos } n\theta \\ \ell_5 &= \sum \ell_5^n \text{ Sin } n\theta \end{aligned}$$

The above series expressions together with Eqs. (1.21) are substituted into Eq. (1.36) and the circumferential variation separated, yielding the following matrix form for the relationship of the Fourier coefficients.

$$\Omega y + \Lambda z = \ell \tag{1.38}$$

where

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ y_k \end{bmatrix} \qquad y_i = \begin{bmatrix} t_\xi^i \\ \hat{t}_{\xi\theta}^i \\ q_\xi^i \\ m_\xi^i \\ m_{\xi\theta}^i \end{bmatrix} \qquad z = \begin{bmatrix} z_1 \\ z_2 \\ \cdot \\ \cdot \\ z_k \end{bmatrix} \qquad z_i = \begin{bmatrix} u_i \\ v_i \\ w_i \\ \phi_{\xi_i} \\ \phi_{\theta_i} \end{bmatrix}$$

$$\Omega = \begin{bmatrix} \bar{\Omega} & & & & \\ & \bar{\Omega} & & & \\ & & \cdot & 0 & \\ & C & & \cdot & \\ & & & & \bar{\Omega}_k \end{bmatrix} \qquad \Lambda = \begin{bmatrix} \bar{\Lambda} & & & \\ & \bar{\Lambda} & 0 & \\ & & \cdot & \\ & 0 & & \cdot \\ & & & & \bar{\Lambda}_k \end{bmatrix}$$

$$\ell = \begin{bmatrix} \bar{\ell}_1 \\ \bar{\ell}_2 \\ \cdot \\ \cdot \\ \bar{\ell}_k \end{bmatrix} \qquad \ell_i = \begin{bmatrix} \ell_{1i} \\ \ell_{2i} \\ \ell_{3i} \\ \ell_{4i} \\ \ell_{5i} \end{bmatrix}$$

It will be desirable to express boundary conditions in terms of z. The substitution of Eqs. (1.37) in Eq. (1.27) with appropriate orthogonality operations yields a set of recursion expressions relating Fourier coefficients of forces and moments to the displacement and stiffness coefficients. These relationships are given by

$$t_{\xi}^{k} = \sum_{j=0}^{K-1} \Big[r_{5k+1,\,5j+1}\, u_j' + r_{5k+1,\,5j+4}\, \phi_{\xi j}' + s_{5k+1,\,5j+1}\, u_j$$

$$+ s_{5k+1,\,5j+2}\, v_j + s_{5k+1,\,5j+3}\, w_j + s_{5k+1,\,5j+4}\, \phi_{\xi j}$$

$$+ s_{5k+1,\,5j+5}\, \phi_{\theta_j} \Big] + a_{5k+1} \qquad (1.39)$$

$$\hat{t}_{\xi\theta}^{k} = \sum_{j=0}^{K-1} \Big[r_{5k+2,\,5j+2}\, v_j' + v_{5k+2,\,5j+5}\, \phi_{\theta_j}' + s_{5k+2,\,5j+1}\, u_j$$

$$+ s_{5k+2,\,5j+2}\, v_j + s_{5k+2,\,5j+4}\, \phi_{\xi_j} + s_{5k+2,\,5j+5}\, \phi_{\theta_j} \Big]$$

$$q_{\xi}^{k} = \sum_{j=0}^{K-1} \left[r_{5k+3,\,5j+2}\, w_j' + s_{5k+3,\,5j+1}\, u_j + s_{5k+3,\,5j+4}\, \phi_{\xi j} \right]$$

$$m_{\xi}^{k} = \sum_{j=0}^{K-1} \left[r_{5k+4,\,5j+1}\, u_j' + r_{5k+4,\,5j+4}\, \phi_{\xi j}' + s_{5k+4,\,5j+1}\, u_j \right.$$

$$+ s_{5k+4,\,5j+2}\, v_j + s_{5k+4,\,5j+3}\, w_j + s_{5k+4,\,5j+4}\, \phi_{\xi j}$$

$$\left. + s_{5k+4,\,5j+5}\, \phi_{\theta j} \right] + a_{T\,5k+4}$$

$$m_{\xi\theta}^{k} = \sum_{j=0}^{K-1} \left[r_{5k+5,\,5j+2}\, v_j' + r_{5k+5,\,5j+5}\, \phi_{\theta j}' + s_{5k+5,\,5j+1}\, u_j \right.$$

$$\left. + s_{5k+5,\,5j+2}\, v_j + s_{5k+5,\,5j+4}\, \phi_{\xi j} + s_{5k+5,\,5j+5}\, \phi_{\theta j} \right]$$

where

$k = 0, 1, 2, \ldots K - 1$

Coefficients are given in Appendix 1-3.

Equation 1.39 can be written in matrix notation as

$$y = Rz' + Sz + a \tag{1.40}$$

Hence, the boundary conditions (1.38) become

$$\Omega R z' + (\Lambda + \Omega s)\, z = \ell - \Omega a \tag{1.41}$$

The form of Eq. (1.41) is modified if the shell has a pole (i.e., $r = o$) because the coefficients of the differential equations become singular for this case. Following a similar limiting process as described by Greenbaum (Reference 5) the conditions supplied at the pole are:

For Fourier index = 0

$$u_o = v_o = \phi_{\xi_o} = \phi_{\theta_o} = q_{\xi_o} = 0 \tag{1.42}$$

For Fourier index = 1

$$u_1 + v_1 = w_1 = \phi_{\xi_1} + \phi_{\theta_1} = t_{\xi_1} - \hat{t}_{\xi\theta_1} = m_{\xi 1} - m_{\xi\theta_1} = 0 \qquad (1.42)$$

For Fourier index ≥ 2

$$u_i = v_i = w_i = \phi_{\xi_i} = \phi_{\theta} = 0$$

1.8 FINITE DIFFERENCE FORMULATION IN THE MERIDIONAL VARIABLE

In a manner similar to that described in Reference 2 the partial differential equation in the matrix form (Equation 1.34) is reduced by a system of finite difference approximations. The variation in the meridional coordinate of the Fourier coefficients are described point-wise in Eq. (1.34). The following are finite difference forms for the partial differentials in the meridional coordinate at interior points.

$$\begin{aligned} \frac{\partial^2 f}{\partial \xi^2} &= \frac{1}{\Delta^2}\left(f_{i+1} - 2f_i + f_{i-1}\right) \\ \frac{\partial f}{\partial \xi} &= \frac{1}{2\Delta}\left(f_{i+1} - f_{i-1}\right) \end{aligned} \qquad (1.43)$$

where Δ is the increment along ξ and subscripts denote the discrete value of the function taken.

The forms at boundary points (initial)

$$\left(\frac{\partial f}{\partial \xi}\right)_1 = \frac{1}{2\Delta}\left(3f_1 - 4f_2 + f_3\right) \qquad (1.44)$$

terminal

$$\left(\frac{\partial f}{\partial \xi}\right)_N = \frac{1}{2\Delta}\left(- f_{N-2} + 4f_{N-1} - 3f_N\right) \qquad (1.45)$$

The result of the application of the various finite difference forms can be stated compactly as the following set of equations:

$$A_o z_2 + B_o z_1 + C_o z_o = g_o$$

$$A_i z_{i+1} + B_i z_i + C_i z_{i-1} = g_i + 2\Delta\left(\alpha_i \ddot{z}_i + \beta_i \dot{z}_i\right) \qquad (1.46)$$

$$A_N z_N + B_N z_{N-1} + C_N z_{N-2} = g_N$$

Where

$$A_o = -\,\Omega_o R_o$$

$$B_o = 2\,\frac{\Omega o}{\Delta} R_o$$

$$C_o = \Lambda_o + \Omega_o S_o - 3\,\frac{\Omega o}{2\Delta}\,R_o$$

$$g_o = \ell_o - \Omega_o a_o$$

the subscript (o) refers to the conditions at $s = 0$.

For $i \neq o,\ N$

$$A_i = \frac{2F_i}{\Delta} + G_i$$

$$B_i = \frac{-4F_i}{\Delta} + 2\Delta\,(H_i + K_i) \qquad (1.47)$$

$$C_i = \frac{2F_i}{\Delta} - G_i$$

$$g_i = 2\Delta p_i$$

Finally for $i = N$ or conditions at $s = \bar{s}$

$$A_N = \Lambda_N + \Omega_N S_N + 3\,\frac{\Omega N}{2\Delta}\,R_N$$

$$B_N = -\,2\,\frac{\Omega N}{\Delta} R_N \qquad (1.48)$$

$$C_N = \frac{\Omega N}{2\Delta}\,R_N$$

$$g_N = \ell_N - \Omega_N a_N$$

1.9 FINITE DIFFERENCE FORMULATION IN THE TIME VARIABLE

By the use of difference equations the above differential equation in matrix form may be transformed into a set of algebraic equations involving the variable z_i at successive values of time.

The most commonly used are the central difference forms; however, from a numerical stability aspect, the difference forms of Houbolt 3, 4 are used. These forms are

$$\ddot{z} = \frac{2z_j - 5z_{j-1} + 4z_{j-2} - z_{j-3}}{\delta^2} \tag{1.49}$$

$$\dot{z} = \frac{11z_j - 18z_{j-1} + 9z_{j-2} - 2z_{j-3}}{6\delta} \tag{1.50}$$

Where the subscript j refers to the time interval j = 0, 1, 2, ... and δ is the time increment.

Introducing these expressions in Eq. 1.46 results in the following set of algebraic equations for the shell response problem.

$$\begin{aligned} A_0 z_{2,j} + B_0 z_{1,j} + C_0 z_{0,j} &= g_0 \\ A_i^* z_{i+1,j} + B_{i,j}^* z_{i,j} + C_i^* z_{i-1,j} &= g_{i,j}^* \\ A_N z_{N,j} + B_N z_{N-1,j} + C_N z_{N-2,j} &= g_N \end{aligned} \tag{1.51}$$

where

$$A_i^* = \delta A_i$$

$$B_{i,j}^* = \delta B_i + 4\frac{\Delta}{\delta}\alpha_i + \frac{11}{3}\Delta\beta_i$$

$$C_i^* = \delta C_i$$

$$g_{i,j}^* = \delta g_i + L_i z_{i,j-1} + M_i z_{i,j-2} + N_i z_{i,j-3}$$

and

$$L_i = 10\frac{\Delta}{\delta}\alpha_i + 6\Delta\beta_i$$

$$M_i = -8\frac{\Delta}{\delta}\alpha_i - 3\Delta\beta_i$$

$$N_i = 2\frac{\Delta}{\delta}\alpha_i + \frac{2}{3}\Delta\beta_i$$

In the real problem no values of z_i exists for less than zero. The assumption that z_i does exist before t = o is a means of allowing the recurrence from Eq. (1.51) to apply at the origin as well as later values of time. Furthermore, no violation is made as long as the initial conditions of t = o are satisfied.

To obtain values for fictitious terms j = -1, -2 a procedure similar to that described by Houbolt is used. The procedure will require a modification of $B^*_{i,j}$, $g^*_{i,j}$ for j = 1, 2.

The difference equations for the first and second derivatives at the third increment of four successive increments are given by

$$\ddot{z}_{i,j} = \frac{1}{\delta^2} (z_{i,j+1} - 2z_{i,j} + z_{i,j-1})$$
$$\dot{z}_{i,j} = \frac{1}{6\delta} (2z_{i,j+1} + 3z_{i,j} - 6z_{i,j-1} + z_{i,j-2}) \qquad (1.52)$$

Applying the equations at t = o, i.e., j = o

$$\ddot{z}_{i,0} = \frac{1}{\delta^2} (z_{i,1} - 2z_{i,0} + z_{i,-1})$$
$$\dot{z}_{i,0} = \frac{1}{6\delta} (2z_{i,1} + 3z_{i,0} - 6z_{i,-1} + z_{i,-2}) \qquad (1.53)$$

The initial conditions are that the displacements and velocities are prescribed at t = o. By application of Newton's second law, a secondary initial condition can be established, i.e., acceleration immediately following application of the initial forces. These conditions are

$$z_{i,o} = d_{i,o}$$
$$\dot{z}_{i,o} = v_{i,o} \qquad (1.54)$$
$$\ddot{z}_{i,o} = a_{i,o}$$

Where $d_{i,o}$, $v_{i,o}$, $a_{i,o}$ are column n matrices formed of the respective coefficients of the Fourier expansions on θ of the initial displacements, velocities, and accelerations at the meridional location i.

Substitution of these values into Eq. (1.53) yields the following relations

$$\begin{aligned} z_{i,o} &= d_{i,o} \\ z_{i,-1} &= \delta^2 a_{i,o} + 2d_{i,o} - z_{i,1} \\ z_{i,-2} &= 6\delta^2 a_{i,o} + 6\delta v_{i,o} + ad_{i,o} - 8z_{i,1} \end{aligned} \tag{1.55}$$

Substitution of these relations in Eq. (1.50) for j = 1 yields the following change in the definitions of Eq. (1.52)

$$\begin{aligned} B^*_{i,1} &= \delta B_i + 12\frac{\Delta}{\delta}\alpha_i + 6\Delta\beta_i \\ g^*_{i,1} &= \delta g_i + \left(12\frac{\Delta}{\delta}\alpha_i + 6\Delta\beta_i\right) d_{i,o} + \left(4\Delta\delta\alpha_i - \frac{7}{3}\delta^2\Delta\beta_i\right) a_{i,o} + \\ &\quad (12\Delta\alpha_i + 4\Delta\delta\beta_i)\, v_{i,o} \end{aligned} \tag{1.56}$$

Substitution of definitions Eq. (1.50) for j = 2 yields the following change in definitions of Eq. (1.52)

$$\begin{aligned} g^*_{i,2} &= \delta g_i + \left(8\frac{\Delta}{\delta}\alpha_i + \frac{16}{3}\beta_i\right) z_{i,1} + \left(-4\frac{\Delta}{\delta}\alpha_i - \frac{5}{3}\Delta\beta_i\right) d_{i,o} + \\ &\quad \left(2\frac{\Delta}{\delta}\alpha_i + \frac{2}{3}\Delta\beta_i\right)\delta^2 a_{i,o} \end{aligned} \tag{1.57}$$

The set of Eq. (1.52) and the additional definitions at the first two time intervals Eqs. (1.56, 1.57) is now the algebraic statement of the dynamic response problem.

1.10 MATRIX SOLUTION OF THE DIFFERENCE EQUATIONS

The set of matrix equations defined in Eqs. 1.51, 1.56, 1.57 will be solved by the same procedure described in Reference 2. This procedure is essentially a Gaussian elimination performed on the partitioned arrays. A slight modification of the elimination procedure described in Reference 6 is used here. Considering the first and second equations of Eq. (1.52) at the j^{th} time interval

$$\begin{aligned} A_o z_{2,j} + B_o z_{1,j} + C_o z_{o,j} &= g_o \\ A_1 z_{2,j} + B^*_1 z_{1,j} + C_1 z_{o,j} &= g^*_{1,j} \end{aligned} \tag{1.58}$$

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The matrix solution of these difference equations are solved by the procedure described in Section 1.10. By defining the starred quantities, ( )*, without the star the numerical procedure for the static analysis is completely defined.

1.12 REFERENCES

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1.13 APPENDIX

1.13.1 Modification of Sander's Equations

Virtual change in the strain energy within C

$$\delta\bar{U} = \iint (N_{11}\delta\epsilon_{11} + N_{12}\delta\epsilon_{12} + N_{21}\delta\epsilon_{21} + N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} + M_{12}\delta k_{12} + M_{21}\delta k_{21} + M_{22}\delta k_{22} + Q_1\delta\gamma_1 + Q_2\delta\gamma_2)\, ds \qquad (1)$$

$$\epsilon_{12} = \epsilon_{21} \qquad (2)$$

$$k_{12} - k_{21} = \left(\frac{1}{R_2} - \frac{1}{R_1}\right)\epsilon_{12} + \frac{1}{\alpha_1\alpha_2}\,\partial\frac{\alpha_2\gamma_2}{\partial\xi_1} - \frac{1}{\alpha_1\alpha_2}\,\partial\frac{\alpha_1\gamma_1}{\partial\xi_2} \qquad (3)$$

Substituting (2) → (1)

$$= \iint \Big| N_{11}\delta\epsilon_{11} + (N_{12} + N_{21})\,\delta\epsilon_{12} + N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} +$$

$$\frac{1}{2} M_{12}\delta k_{12} + \frac{1}{2} M_{12}\delta k_{12} + \frac{1}{2} M_{21}\delta k_{21} + \frac{1}{2} M_{21}\delta k_{21} + \tag{4}$$

$$\frac{1}{2} M_{21}\delta k_{12} - \frac{1}{2} M_{21}\delta k_{12} + \frac{1}{2} M_{12}\delta k_{21} - \frac{1}{2} M_{12}\delta k_{21} +$$

$$M_{22}\delta k_{22} + Q_1\delta\gamma_1 + Q_2\delta\gamma_2 \Big| \alpha_1\alpha_2 d\xi_1 d\xi_2$$

Rearrange

$$= \iint \Big| N_{11}\delta\epsilon_{11} + (N_{12} + N_{21})\,\delta\epsilon_{12} + N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} +$$

$$\frac{1}{2}(M_{12} - M_{21})\,\delta\,(k_{12} - k_{21}) + \frac{1}{2}(M_{12} + M_{21})\,\delta k_{21} + \tag{5}$$

$$\frac{1}{2}(M_{12} + M_{21})\,\delta k_{12} + M_{22}\delta k_{22} + Q_1\delta\gamma_1 + Q_2\delta\gamma_2 \Big| \alpha_1\alpha_2 d\xi_1 d\xi_2$$

Substitute 3 → 5.

$$\iint \Big| N_{11}\delta\epsilon_{11} + (N_{12} + N_{21})\,\delta\epsilon_{12} + N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} +$$

$$\frac{1}{2}(M_{12} - M_{21})\,\delta\left(\left(\frac{1}{R_2} - \frac{1}{R_1}\right)\epsilon_{12} + \frac{1}{\alpha_1\alpha_2}\frac{\partial\alpha_2\gamma_2}{\partial\xi_1} -\right.$$

$$\left.\frac{1}{\alpha_1\alpha_2}\frac{\partial\alpha_1\gamma_1}{\partial\xi_2}\right) + \frac{1}{2}(M_{21} + M_{12})\,\delta\,(k_{12} + k_{21}) + M_{22}\delta k_{22} +$$

$$Q_1\delta\gamma_1 + Q_2\delta\gamma_2 \Big| \alpha_1\alpha_2 d\xi_1 d\xi_2$$

Group.

$$\iint \Big\{ N_{11}\delta\epsilon_{11} + 2\left(\frac{1}{2}(N_{12} + N_{21}) + \frac{1}{4}\left(\frac{1}{R_2} - \frac{1}{R_1}\right)(M_{12} - M_{21})\right)\delta\epsilon_{12} +$$

$$N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} + \frac{1}{2\alpha_1\alpha_2}(M_{12} - M_{21})\,\delta\left(\frac{\partial\alpha_2\gamma_2}{\partial\xi_1} - \frac{\partial\alpha_1\gamma_1}{\partial\xi_2}\right) +$$

$$\frac{1}{2}(M_{21} + M_{12})\,\delta\,(k_{12} + k_{21}) + M_{22}\delta k_{22} + Q_1\delta\gamma_1 + Q_2\delta\gamma_2 \Big\}\, \alpha_1\alpha_2 d\xi_1 d\xi_2$$

Expanding $\delta \frac{\partial}{\delta\xi}(\alpha\gamma)$

$$\delta\left(\frac{\partial\alpha_2\gamma_2}{\partial\xi_1} - \frac{\partial\alpha_1\gamma_1}{\partial\xi_2}\right) = \delta\left(\gamma_2\frac{\partial\alpha_2}{\partial\xi_1} + \alpha_2\frac{\partial\gamma_2}{\partial\xi_1} - \gamma_1\frac{\partial\alpha_1}{\partial\xi_2} - \alpha_1\frac{\partial\gamma_1}{\partial\xi_2}\right)$$

Substitute and Group.

$$\iint \Big\{ N_{11}\delta\epsilon_{11} + 2\left[\frac{1}{2}(N_{12} + N_{21}) + \frac{1}{4}\left(\frac{1}{R_2} - \frac{1}{R_1}\right)(M_{12} - M_{21})\right]\delta\epsilon_{12} +$$

$$N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} + \frac{1}{2}(M_{21} + M_{12})\,\delta\,(k_{12} + k_{21}) + M_{22}\delta k_{22} +$$

$$\left[Q_1 - \frac{1}{2\alpha_1\alpha_2}\frac{\partial\alpha_1}{\partial\xi_2}(M_{12} - M_{21})\right]\delta\gamma_1 + \left[Q_2 + \frac{1}{2\alpha_1\alpha_2}\frac{\partial\alpha_2}{\partial\xi_1}(M_{12} - M_{21})\right]$$

$$\delta\gamma_2 + \frac{1}{2}(M_{12} - M_{21})\,\delta\left(\frac{1}{\alpha_1}\frac{\partial\gamma_2}{\partial\xi_1} - \frac{1}{\alpha_2}\frac{\partial\gamma_1}{\partial\xi_2}\right)\Big\}\,\alpha_1\alpha_2 d\xi_1 d\xi_2$$

Assumption

$$M_{12} - M_{21} \rightarrow o, \quad \frac{\delta\partial\gamma_i}{\partial\xi_j} << \delta\,(\epsilon,\ k)$$

$$\iint \Big\{ N_{11}\delta\epsilon_{11} + 2\overline{N}_{12}\delta\epsilon_{12} + N_{22}\delta\epsilon_{22} + M_{11}\delta k_{11} + M_{22}\delta k_{22} +$$

$$2\overline{M}_{12}\delta\overline{k}_{12} + Q_1\delta\gamma_1 \quad Q_2\delta\gamma_2 \Big\}\,\alpha_1\alpha_2 d\xi_1 d\xi_2$$

$$\overline{N}_{12} = \frac{1}{2}(N_{12} + N_{21})$$

$$\overline{M}_{12} = \frac{1}{2}(M_{12} + M_{21})$$

$$\overline{k}_{12} = \frac{1}{2}(k_{12} + k_{21})$$

1.132 Multiplication of Series Expansions

The relationships A^{nj} and $\overline{A}^{nj}$ used in the text are found by multiplying term by term the series expansions of stiffness and strain and noting a recurring sequence of the resulting expressions

$$\text{e.g.,}\ \left(\sum_{j=0}^{K-1} b_j \,\text{Cos}\, j\theta\right)\left(\sum_{n=0}^{K-1} \epsilon_{\xi n} \,\text{Cos}\, n\theta\right) = \sum_{n=0}^{K-1}\left(\sum_{j=0}^{K-1} A^{nj}\epsilon_{\xi j}\right)\text{Cos}\, n\theta$$

$$= \sum_{n=0}^{K-1}\left\{\sum_{j=0}^{K-1}\frac{1}{2}\Big[b^{(n+j)} + \Big[1 - \delta^2(j-k) + \delta(k)\Big]\, b^{|n-j|}\Big]\,\epsilon_{\xi j}\right\}\text{Cos}\, n\theta$$

$$\left(\sum_{j=0}^{K-1} b_j \,\text{Cos}\, j\theta\right)\left(\sum_{n=1}^{K-1} \overline{\epsilon}_{\xi n} \,\text{Sin}\, n\theta\right) = \sum_{n=1}^{K-1}\left(\sum_{j=0}^{K-1} \overline{A}^{nj}\overline{\epsilon}_{\xi j}\right)\text{Sin}\, n\theta$$

$$= \sum_{n=1}^{K-1}\left\{\sum_{j=0}^{K-1}\frac{1}{2}\Big[-\,b^{(n+j)} + \Big[1 - \delta^2(j-k) + \delta(k)\Big]\, b^{|n-j|}\Big]\,\overline{\epsilon}_{\xi j}\right\}\text{Sin}\, n\theta$$

where

$$\delta(m) = \begin{cases} -1 & m < 0 \\ 0 & m = 0 \\ +1 & m > 0 \end{cases}$$

1.133 Coefficients

Stiffness parameters related in an isotropic manner

$$B_1 = B_2 = \frac{B_3}{\nu}$$

$$D_1 = D_2 = \frac{D_3}{\nu}$$

$$G_1 = G_2 = G_3 = \frac{B_1 (1 - \nu)}{2}$$

$$G_{13} = \frac{D_1 (1 - \nu)}{2}$$

$$f_{5k+1, 5j+1} = B_1^{kj}$$

$$f_{5k+1, 5j+4} = 0$$

$$f_{5k+2, 5j+2} = \frac{G_1^{kj}}{2} + \frac{\lambda^2}{8} (\omega_\theta - \omega_\xi)^2 G_{13}^{kj}$$

$$f_{5k+2, 5j+5} = \frac{\lambda^2}{4} (\omega_\theta - \omega_\xi) G_{13}^{kj}$$

$$f_{5k+3, 5j+3} = G_2^{kj}$$

$$f_{5k+4, 5j+1} = 0$$

$$f_{5k+4, 5j+4} = \lambda^2 D_1^{kj}$$

$$f_{5k+5, 5j+2} = \frac{\lambda^2}{4} (\omega_\theta - \omega_\xi) G_{13}^{kj}$$

$$f_{5k+5, 5j+5} = \frac{\lambda^2}{2} G_{13}^{kj}$$

$$g_{5k+1, 5j+1} = B_1^{kj\,\prime} + \gamma B_1^{kj}$$

$$g_{5k+1, 5j+2} = \frac{k}{\rho} B_3^{kj} + \frac{k}{2\rho} G_1^{kj} - \frac{\lambda^2 k}{8\rho} (\omega_\theta - \omega_\xi)^2 G_{13}^{kj}$$

$$g_{5k+1, 5j+3} = \omega_\xi B_1^{kj} + \omega_\theta B_3^{kj} + \omega_\xi G_2^{kj}$$

$$g_{5k+1, 5j+4} = 0$$

$$g_{5k+1,\,5j+5} = +\frac{\lambda^2 k}{4\rho}(\omega_\xi - \omega_\theta)\,G_{13}^{kj}$$

$$g_{5k+2,\,5j+1} = -\frac{k}{2\rho}\,G_1^{kj} + \frac{\lambda^2 k}{8\rho}(\omega_\theta - \omega_\xi)^2\,G_{13}^{kj} - \frac{k}{\rho}\,B_3^{kj}$$

$$g_{5k+2,\,5j+2} = \frac{G_1^{kj\prime}}{2} + \frac{\gamma}{2}\,G_1^{kj} + \frac{\lambda^2}{8}(\omega_\theta - \omega_\xi)^2\,G_{13}^{kj\prime} - \frac{\lambda^2}{8}\left(\gamma\,(\omega_\theta - \omega_\xi)^2 + 2\,\omega_\xi'\,(\omega_\theta - \omega_\xi)\right)G_{13}^{kj}$$

$$g_{5k+2,\,5j+4} = -\frac{\lambda^2}{4}\frac{k}{\rho}(\omega_\theta - \omega_\xi)\,G_{13}^{kj}$$

$$g_{5k+2,\,5j+5} = +\frac{\lambda^2}{4}(\omega_\theta - \omega_\xi)\,G_{13}^{kj\prime} + \frac{\lambda^2}{4}\left(2\gamma\,(\omega_\xi - \omega_\theta) - \omega_\xi'\right)G_{13}^{kj}$$

$$g_{5k+3,\,5j+1} = -\,\omega_\xi G_2^{kj} - \omega_\xi B_1^{kj} - \omega_\theta B_3^{kj}$$

$$g_{5k+3,\,5j+3} = G_2^{kj\prime} + \gamma G_2^{kj}$$

$$g_{5k+3,\,5j+4} = G_2^{kj}$$

$$g_{5k+4,\,5j+1} = 0$$

$$g_{5k+4,\,5j+2} = +\frac{\lambda^2}{4}\frac{k}{\rho}(\omega_\theta - \omega_\xi)\,G_{13}^{kj}$$

$$g_{5k+4,\,5j+3} = -\,G_2^{kj}$$

$$g_{5k+4,\,5j+4} = \lambda^2 D_1^{kj\prime} + \gamma\lambda^2 D_1^{kj}$$

$$g_{5k+4,\,5j+5} \quad = \lambda^2 \frac{k}{\rho} D_3^{kj} + \frac{\lambda^2}{2}\frac{k}{\rho} G_{13}^{kj}$$

$$g_{5k+5,\,5j+1} \quad {}^{2}\,\frac{k}{\rho}(\omega_\theta - \omega_\xi)\, G_1^{kj}$$

$$g_{5k+5,\,5j+2} \quad = +\frac{\lambda^2}{4}(\omega_\theta - \omega_\xi)\, G_{13}^{kj\,\prime} + \frac{\lambda^2}{4}\left(2\gamma\,(\omega_\theta - \omega_\xi) - \omega_\xi'\right) G_{13}^{kj}$$

$$g_{5k+5,\,5j+4} \quad = -\frac{\lambda^2}{2}\frac{k}{\rho} G_{13}^{kj} - \lambda^2 \frac{k}{\rho} D_3^{kj}$$

$$g_{5k+5,\,5j+5} \quad = \frac{\lambda^2}{2} G_{13}^{kj\,\prime} + \frac{\lambda^2}{2}\gamma G_{13}^{kj}$$

$$h_{5k+1,\,5j+1} \quad = \gamma B_3^{kj\,\prime} - \omega_\xi\omega_\theta B_3^{kj} - \gamma^2 B_2^{kj} - \frac{k^2}{2\rho^2} G_1^{kj} - \frac{\lambda^2}{8}\frac{k^2}{\rho^2}(\omega_\theta - \omega_\xi)^2 G_{13}^{kj} -$$

$$\omega_\xi^2 G_2^{kj}$$

$$h_{5k+1,\,5j+2} \quad = \frac{k}{\rho} B_3^{kj\,\prime} \quad \vee \frac{k}{\rho} B_2^{kj} - \frac{\gamma}{2}\frac{k}{\rho} G_1^{kj} - (\omega_\xi - \omega_\theta)^2 \frac{\gamma\lambda^2}{8}\frac{k}{\rho} G_{13}^{kj}$$

$$h_{5k+1,\,5j+3} \quad = \omega_\xi B_1^{kj\,\prime} + \omega_\theta B_3^{kj\,\prime} + (\omega_\xi' + \gamma\omega_\xi)\, B_1^{kj} - \gamma\omega_\theta B_2^{kj}$$

$$h_{5k+1,\,5j+4} \quad = +\,\omega_\xi G_2^{kj} + \frac{\lambda^2}{4}\frac{k^2}{\rho^2}(\omega_\theta - \omega_\xi)\, G_{13}^{kj}$$

$$h_{5k+1,\,5j+5} \quad = +\frac{\lambda^2\gamma}{4}\frac{k}{\rho}(\omega_\theta - \omega_\xi)\, G_{13}^{kj}$$

$$h_{5k+2,\,5j+1} \quad = -\frac{k}{2\rho} G_1^{kj\,\prime} - \frac{\gamma k}{2\rho} G_1^{kj} - \frac{k}{\rho}\gamma B_2^{kj} + \frac{\lambda^2}{8}\frac{k}{\rho}(\omega_\theta - \omega_\xi)^2 G_{13}^{kj\,\prime} -$$

$$\frac{\lambda^2}{8}\frac{k}{\rho}(\omega_\theta - \omega_\xi)\left(3\gamma\,(\omega_\theta - \omega_\xi) - 2\omega_\xi'\right) G_{13}^{kj}$$

$$h_{5k+2,\,5j+2} = \frac{1}{2}(\omega_\xi\omega_\theta - \gamma^2)\,G_1^{kj} - \frac{\gamma}{2}\,G_1^{kj\,\prime} - \frac{k^2}{\rho^2}\,B_2^{kj} - \omega_\theta^2 G_{13}^{kj} +$$

$$\frac{\lambda^2\gamma}{8}(\omega_\theta - \omega_\xi)^2\,G_{13}^{kj\,\prime} - \frac{\lambda^2}{8}\Big((\omega_\theta - \omega_\xi)^2\,(\omega_\xi\omega_\theta + 3\gamma^2) -$$

$$(\omega_\xi - \omega_\theta)\,2\gamma\omega'_\xi\Big)\,G_{13}^{kj}$$

$$h_{5k+2,\,5j+3} = -\frac{k}{\rho}\,\omega_\xi B_3^{kj} - \frac{k}{\rho}\,\omega_\theta B_2^{kj} - \omega_\theta\,\frac{k}{\rho}\,G_3^{kj}$$

$$h_{5k+2,\,5j+4} = +\frac{\lambda^2}{4}\,\frac{k}{\rho}\,\gamma\,\Big(2\,(\omega_\theta - \omega_\xi) + \omega'_\xi\Big)\,G_{13}^{kj} - \frac{\lambda^2}{4}\,\frac{k}{\rho}(\omega_\theta - \omega_\xi)\,G_{13}^{kj\,\prime}$$

$$h_{5k+2,\,5j+5} = +\,\omega_\theta G_3^{kj} - \frac{\lambda^2\gamma}{4}(\omega_\theta - \omega_\xi)\,G_{13}^{kj\,\prime} + \frac{\lambda^2}{4}(\omega_\theta - \omega_\xi)\,(\omega_\xi\omega_\theta + 2\gamma^2)\,G_{13}^{kj} +$$

$$\frac{\lambda^2\gamma}{4}\,\omega'_\xi G_{13}^{kj}$$

$$h_{5k+3,\,5j+1} = -\,(\omega'_\xi + \gamma\omega_\xi)\,G_2^{kj} - \omega_\xi\gamma B_3^{kj} - \omega_\theta\gamma B_2^{kj} - \omega_\xi G_2^{kj\,\prime}$$

$$h_{5k+3,\,5j+2} = -\frac{k}{\rho}\,\omega_\xi B_3^{kj} - \frac{k}{\rho}\,\omega_\theta B_2^{kj} - \omega_\theta\,\frac{k}{\rho}\,G_3^{kj}$$

$$h_{5k+3,\,5j+3} = -\frac{k^2}{\rho^2}\,G_3^{kj} - \omega_\xi^2 B_1^{kj} - 2\,\omega_\theta\omega_\xi B_3^{kj} - \omega_\theta^2 B_2^{kj}$$

$$h_{5k+3,\,5j+4} = G_2^{kj\,\prime} + \gamma G_2^{kj}$$

$$h_{5k+3,\,5j+5} = \frac{k}{\rho}\,G_3^{kj}$$

$$h_{5k+4,\,5j+1} = +\,\frac{k^2}{4\rho^2}\,\lambda^2\,(\omega_\theta - \omega_\xi)\,G_{13}^{kj} + \omega_\xi G_2^{kj}$$

$$h_{5k+4,\,5j+2} = +\,\frac{\lambda^2}{4}\,\frac{k}{\rho}\,\gamma\,(\omega_\theta - \omega_\xi)\,G_{13}^{kj}$$

$$h_{5k+4,\,5j+3} = 0$$

$$h_{5k+4,\,5j+4} = -\lambda^2\omega_\xi\omega_\theta D_3^{kj} + \lambda^2\gamma D_3^{kj\,\prime} - \frac{\lambda^2 k^2}{2\rho^2} G_{13}^{kj} - \gamma^2\lambda^2 D_2^{kj} - G_2^{kj}$$

$$h_{5k+4,\,5j+5} = \lambda^2 \frac{k}{\rho} D_3^{kj\,\prime} - \frac{\lambda^2\gamma}{2} \frac{k}{\rho} G_{13}^{kj} - \lambda^2\gamma \frac{k}{\rho} D_2^{kj}$$

$$h_{5k+5,\,5j+1} = +\frac{\lambda^2}{4} \frac{k}{\rho} (\omega_\theta - \omega_\xi)\, G_{13}^{kj\,\prime} - \frac{\lambda^2}{4} \frac{k}{\rho}\, \omega_\xi' G_{13}^{kj}$$

$$\begin{aligned} h_{5k+5,\,5j+2} = {} & +\frac{\lambda^2\gamma}{4} (\omega_\theta - \omega_\xi)\, G_{13}^{kj\,\prime} - \frac{\lambda^2}{4} \Big(\gamma\omega_\xi' + \omega_\xi\omega_\theta\, (\omega_\theta - \omega_\xi)\Big)\, G_{13}^{kj} + \\ & \omega_\theta G_3^{kj} \end{aligned}$$

$$h_{5k+5,\,5j+3} = +\frac{k}{\rho} G_3^{kj}$$

$$h_{5k+5,\,5j+4} = -\frac{\lambda^2}{2} \frac{k}{\rho} G_{13}^{kj\,\prime} - \lambda^2 \frac{k}{\rho} \gamma D_2^{kj} - \frac{\lambda^2}{2} \frac{k}{\rho} \gamma G_{13}^{kj}$$

$$h_{5k+5,\,5j+5} = -\frac{\lambda^2\gamma}{2} G_{13}^{kj\,\prime} - \lambda^2 \frac{k^2}{\rho^2} D_2^{kj} - G_3^{kj} + \frac{\lambda^2}{2} (\omega_\xi\omega_\theta - \gamma^2)\, G_{13}^{kj}$$

$$p_{5k+1} = -p_\xi^k + t_{\xi T}^{k\,\prime} + \gamma\, (t_{\xi T}^k - t_{\theta T}^k)$$

$$p_{5k+2} = -p_\theta^k - \frac{k}{\rho} t_{\theta T}^k$$

$$p_{5k+3} = -p^k - \omega_\xi t_{\xi T}^k - \omega_\theta t_{\theta T}^k$$

$$p_{5k+4} = \lambda^2 m_{\xi T}^{k\,\prime} + \lambda^2\gamma m_{\xi T}^k - \lambda^2\gamma m_{\theta T}^k$$

$$p_{5k+5} = -\frac{k}{\rho} \lambda^2 m_{\theta T}^k$$

$$r_{5k+1,\,5j+1} = B_1^{kj}$$

$$r_{5k+1,\,5j+4} = 0$$

$$r_{5k+2,\,5j+2} = \frac{1}{2} G_1^{kj} + \frac{\lambda^2}{8} (\omega_\theta - \omega_\xi)^2 G_{13}^{kj}$$

$$r_{5k+2,\,5j+5} = + \frac{\lambda^2}{4} (\omega_\theta - \omega_\xi) G_{13}^{kj}$$

$$r_{5k+3,\,5j+3} = G_2^{kj}$$

$$r_{5k+4,\,5j+1} = 0$$

$$r_{5k+4,\,5j+4} = D_1^{kj}$$

$$r_{5k+5,\,5j+2} = + \left(\frac{\omega_\theta - \omega_\xi}{4}\right) G_{13}^{kj}$$

$$r_{5k+5,\,5j+5} = \frac{1}{2} G_{13}^{kj}$$

$$s_{5k+1,\,5j+1} = \gamma B_3^{kj}$$

$$s_{5k+1,\,5j+2} = \frac{k}{\rho} B_3^{kj}$$

$$s_{5k+1,\,5j+3} = \omega_\xi B_1^{kj} + \omega_\theta B_3^{kj}$$

$$s_{5k+1,\,5j+4} = 0$$

$$s_{5k+1,\,5j+5} = 0$$

$$s_{5k+2,\,5j+1} = - \frac{k}{2\rho} G_1^{kj} + \frac{\lambda^2}{8} \frac{k}{\rho} (\omega_\theta - \omega_\xi)^2 G_{13}^{kj}$$

$$s_{5k+2,\,5j+2} = -\frac{\gamma}{2} G_1^{kj} + \frac{\lambda^2}{8} \gamma \,(\omega_\theta - \omega_\xi)^2\, G_{13}^{kj}$$

$$s_{5k+2,\,5j+4} = -\frac{\lambda^2}{4} \frac{k}{\rho} (\omega_\theta - \omega_\xi)\, G_{13}^{kj}$$

$$s_{5k+2,\,5j+5} = -\frac{\gamma \lambda^2}{4} (\omega_\theta - \omega_\xi)\, G_{13}^{kj}$$

$$s_{5k+3,\,5j+4} = -\,\omega_\xi G_2^{kj}$$

$$s_{5k+3,\,5j+4} = G_2^{kj}$$

$$s_{5k+4,\,5j+1} = 0$$

$$s_{5k+4,\,5j+2} = 0$$

$$s_{5k+4,\,5j+3} = 0$$

$$s_{5k+4,\,5j+4} = \gamma D_3^{kj}$$

$$s_{5k+4,\,5j+5} = \frac{k}{\rho} D_3^{kj}$$

$$s_{5k+5,\,5j+1} = +\frac{k}{4\rho} (\omega_\theta - \omega_\xi)\, G_{13}^{kj}$$

$$s_{5k+5,\,5j+2} = +\frac{\gamma}{4} (\omega_\theta - \omega_\xi)\, G_{13}^{kj}$$

$$s_{5k+5,\,5j+4} = -\frac{k}{2\rho} G_{13}^{kj}$$

$$s_{5k+5,\,5j+5} = -\frac{\gamma}{2} G_{13}^{kj}$$

$$a_{5k+1} = - t^{k}_{\xi T}$$

$$a_{5k+4} = - m^{k}_{\xi T}$$

All other r, s, a are equal to zero.

2.0 GENERAL DESCRIPTION OF COMPUTER PROGRAMS

2.1 INTRODUCTION

Both the Static and Dynamic analysis described in Section 1.0 are programmed for solution on the IBM 7094 digital computer using the IBM FORTRAN IV code. This section will give a general description of the two computer programs. The scope and limitations of the computer programs are outlined. The necessary quantities in selecting a mathematical model for the best utilization of the programs are described. The detailed description, the machine program, input instructions, flow diagram, sample data sheets, etc., are given in Section 3.0.

2.2 PROGRAM CAPABILITIES AND LIMITATIONS

Before describing some of the general program characteristics, it will perhaps be worthwhile to list some of the capabilities which 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. Shells having meridional and circumferential variation in the stiffness properties can be analyzed. The circumferential variation must have a property of symmetry about some plane, θ = constant (constant = 0).

b. Static shells can be subjected to loads and temperatures which may vary meridionally and circumferentially with the limitation that these distributions must exhibit the same property of symmetry as the stiffness. The time dependent loadings for the dynamic response of shells must have the same conditions on the special distributions and also can vary arbitrarily in time.

c. For static shells, elastic foundations can be considered. The distribution of these parameters are subject to the same condition of symmetry described for stiffness. For the dynamic response, both elastic foundations and external dampings are considered. These are also subject to the same symmetry conditions imposed on the stiffness parameters.

d. Shells analyzed must have a surface of revolution reference surface. The middle surface of the shell has been taken as the reference surface for these computer programs, i.e., the section properties must be symmetric about the reference surface ($\int E\zeta d\zeta = 0$).

e. User compiled call functions are used in place of tables to input data of a 2 and 3 variable nature.

f. As many as 100 spacial integration intervals can be considered.

g. The Fourier expansions can be taken to 10 terms.

2.3 SIGN CONVENTIONS AND DIMENSIONS

The sign conventions used in the programs are illustrated in Figures (1.2, 1.3) in Section 1.0. To augment briefly 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 surfaces and compressive stresses in the outer surface (see Section 2.4). The extensional displacement u, transverse deflection w, and meridional rotation Φ_ξ, are positive when the ξ and ζ coordinates are increased respectively.

In using the program, all data specified must be dimensionally consistent.

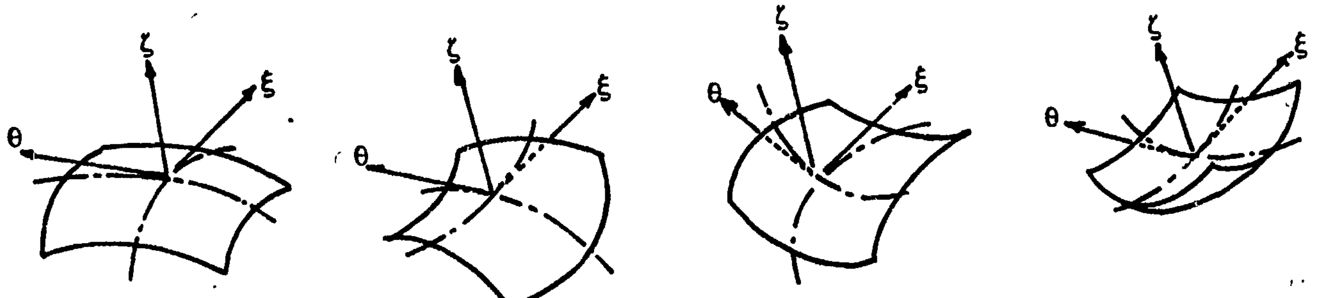
2.4 REFERENCE, INNER, AND OUTER SURFACES

The reference surface $\zeta = 0$ is chosen such that the requirements of limitation (d) above 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., ρ, γ), 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 1.6 Eq. 1.17.

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 inner surface is on the right when the geometry is drawn with axial distance increasing from top to bottom and radial distance from left to right as shown in Figure 1.1.

2.5 GEOMETRY (GIN)

Geometric parameters must be defined at each station location. The sign convention for the curvature parameters, ω_ξ, ω_θ are defined in the figures below.



$\omega_\xi > 0$ $\omega_\theta > 0$ $\omega_\xi < 0$ $\omega_\theta > 0$ $\omega_\xi > 0$ $\omega_\theta < 0$ $\omega_\xi < 0$ $\omega_\theta < 0$

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 (GIN).

2.5.1 Cone-Cylinder Option (GIN) = 1.0)

This geometry option may be specified for a complete range of regional configurations generated by a straight line, e.g., circular plates, divergent cones, cylinders and convergent cones. A minimum of 3 input parameters are 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.

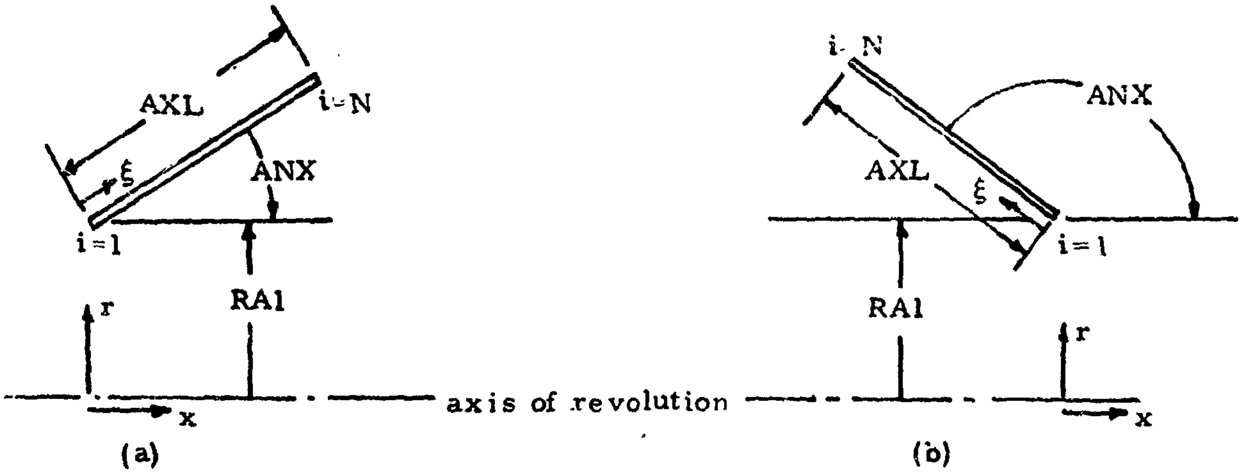


Figure 2.1 Cone Cylinder Geometry

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 2.1.

2.5.2 Sphere-Toroid (GIN = 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.

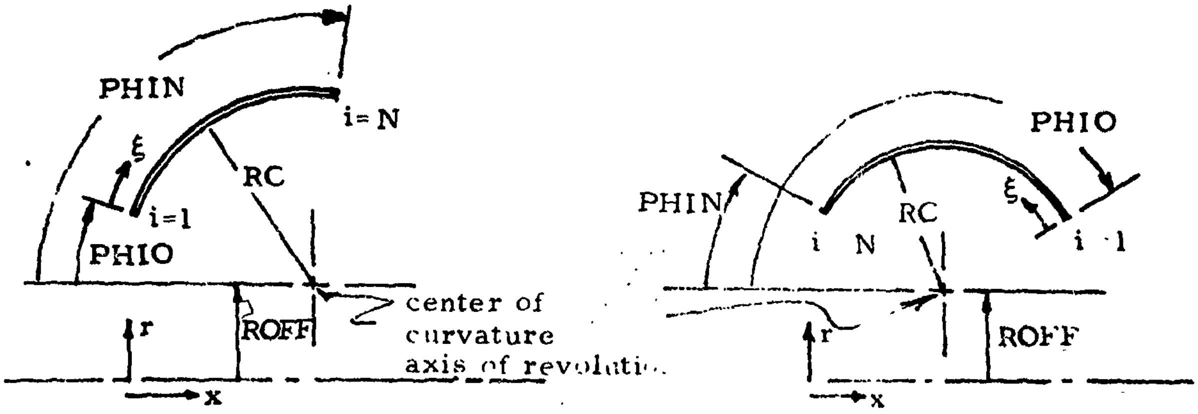


Figure 2.2 Sphere Toroid Geometry

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.

2.5.3 Discrete Point Option (GIN = ±4.0)

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 (GIN = +4.0), 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 (GIN = -4.0), 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 2.3.) 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 are adhered to.

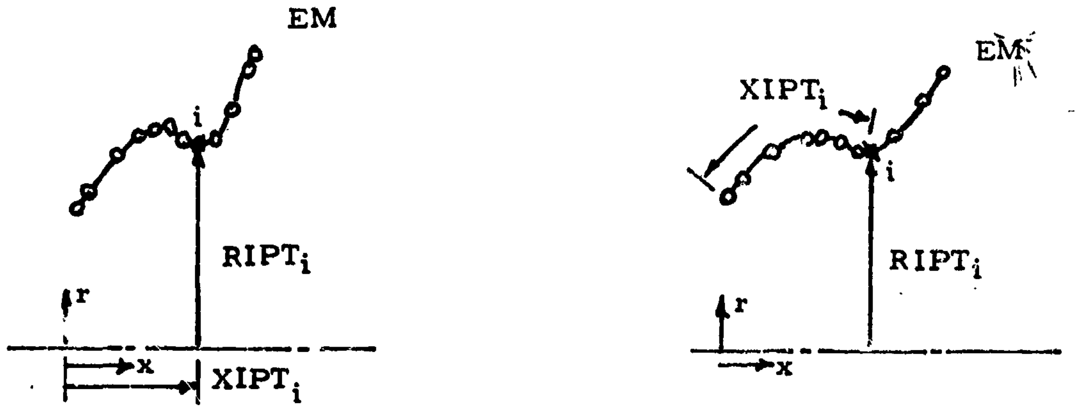


Figure 2.3

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 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 GIN = +4.0 and GIN = -4.0. When no values are input at RCURV and RCURZ locations, the curvatures will be computed from the discrete point set of RIPT and XIPT.

2.6 CALL FUNCTION PARAMETERS

Input data of a multivariable nature are defined to the computer programs by the use of call function subroutines. These parameters are described functional in terms of the meridional and circumferential variables (PEL, ZTA). The time variable (TU) is available for describing the loading history. Call function subroutines are to be coded and compiled by the user. Specific instructions for the coding of these subroutines are given in Section 3. Data that will be input in this manner are described in the following sections.

2.6.1 Stiffness Properties

The stiffness parameters are described in Section 1.6, Equations 1.16. It is sufficient to describe the inplane stiffness B_1, and the bending stiffness D_1 and Poisson's ratio in order to define all the necessary parameters. The function (BFCN, Static, DBBDD, Dynamics) will be written to define these parameters over the reference surface of the shell.

$$B_1 = B_1 (\xi, \theta)$$

$$D_1 = D_1 (\xi, \theta)$$

2.6.2 Thermal Loads

The thermal load terms are described in Section 1.6, Equation 1.15 The call function (TFCN, Static, DTMP, Dynamics) will be written to define these parameters over the reference surface of the shell.

$$N_\xi^T = N_\xi^T (\xi, \theta)$$

$$M_\xi^T = M_\xi^T (\xi, \theta)$$

2.6.3 Elastic Foundations

The elastic foundation parameters are defined in Section 1.6, Equation 1.6. For the static program these parameters will be defined in function subroutine KFCN. For the dynamic program these parameters will be defined in DKMP.

2.6.4 External Damping

The external damping parameters are defined in Section 1.6, Equation 1.6. In the Dynamics program this function subroutine, DKMP will define both the elastic foundation terms and the external damping parameters.

2.6.5 Mass Properties

The mass properties for the Dynamic program defined in Section 1.6, Equation1.6 are defined to the computer program in the subroutine DMASS.

2.6.6 Pressure Loads

The pressure loading for the static case is defined to the program in the subroutine PFCN. For the dynamic case the time dependent loading is defined to the computer program in the subroutine PRSS. Positive pressure yields positive displacement.

2.6.7 Parameters for Stresses

For the static program, the parameters necessary for the computation of stresses are defined to the computer program by the following subroutines, STR1FN, STR2FN, TTF1, TTF2. These subroutines define the following parameters:

STR1FN, for the first stress print layer, EI1, Young's Modulus, DN1, distance from the reference surface to the stress print locations and POIS1, Poisson's ratio.

STR2FN, these are parameters necessary for stresses at a second layer. The definitions of EI2, DN2, POIS2 correspond to the first stress print parameters.

TTF1, this subroutine defines the temperature TMP1 and thermal expansion coefficient ALF1 at the first stress print location.

TTF2, these parameters are for the second stress print and the TMP2, ALF2 have definitions corresponding to TTF1.

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 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 $s = 0$) and the last or EN-th station at the end of the region called station N ($i = N$ or $s = \bar{s}$). 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 100 (minimum 5). 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.

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

3.0 DETAILED USE OF PROGRAMS

3.1 INTRODUCTION

The Unsymmetric Shell Computer Program is written in the FORTRAN IV language and makes use of the overlay feature and the ALTIO option of that language. ALTIO sacrifices speed of execution in favor of providing an additional 1900 core locations. (It does not make use of buffered input-output.) If the programs are to be compiled for use without the ALTIO option it will be necessary to add an additional BACKSPACE command at each location where the backspace moved the tape over an END OF FILE. These have been noted in the listings.

The program has been checked out in NAASYS, the NAA adaption of the IBM 7090/7094 IBSYS/IBJOB system and used the NAASYS library routines shown in the load map, Section 3.12m.

The NAASYS input tape is 'UNIT05'; the output tape is 'UNIT06'. In addition to these files, the program uses units 3, 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 eleven links, four of which are called by the executive program, three by the DATLNK subroutine and four by the PANDX subroutine. The name of the main program in each link and a description of its use, follows.

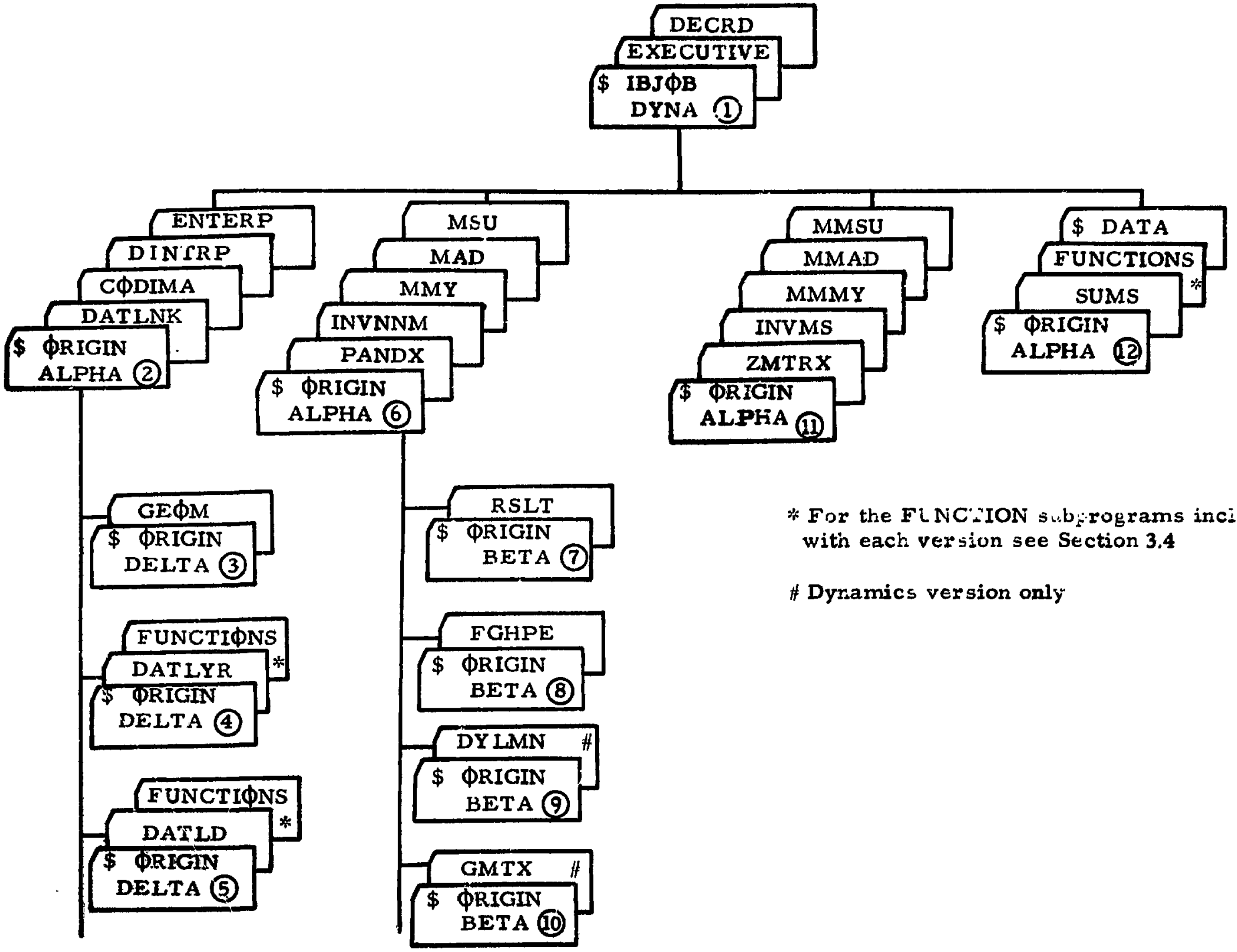
Link No.	Name	Purpose
0	Executive	Reads the title cards and general data; sets up tape numbers and rewinds all tapes; controls the flow of execution of other links.
1	DATLNK	Acts as a sub-executive program to control GEOM, DATLYR and DATLD so that these three subroutines may share common auxiliary routines CODIMA, ENTERP and DINTRP.
2	GEOM	Reads geometry parameters, GMDA. Sets up top and bottom boundary matrices. Calculates DEL, R, XSI, WTHX, WFEX, GAMA, RHOX, WFEPX and stores the latter 5 arrays on tape. Prints general data, boundary matrices and pertinent geometry data on indicator.

Link No.	Name	Purpose
3	DATLYR	Sets up stiffness and temperature coefficients by function subprograms. These are stored on tape.
4	DATLD	This is the Fourier Load coefficients generator. Pressures, PFE, PTH and PN are supplied by function subprograms. These coefficients are preserved on tape.
5	PANDX	A sub-executive program which, together with the subroutines it controls--RSLT, FGHPE, DYLMN, GMTX--generates the recursion terms and the 'P' and 'X' matrices of equations 1.60 Section 1.10.
6	RSLT	Sets up the boundary matrices needed in computing 'P' and 'X' at the top and bottom of the shell. (See Section 1.10.)
7	FGHPE	Sets up the F, G, and H matrices in equilibrium equations 1.34 of Section 1.7.
8	DYLMN*	Sets up the L, M, and N matrices for the dynamic response equations of Section 1.9. These are written on tape 13.
9	GMTX*	Forms the PE matrix of equation 1.34 of Section 1.7. Computes 'G**', 'B**', 'P' and 'X' matrices.
10	ZMTRX	Computes 'Z', the solution matrix.
11	SUMS	Sums the Fourier components and computes internal loads, i.e., bending moments, transverse shear forces, and membrane forces. (In the static version, stresses may also be computed in this link with the parameters defined by function subprograms.)

*Dynamics version only

3.2 DECK SET-UP

In Figure 3A of this section we have shown the set-up of the column-binary program deck with the necessary control cards for each link. A list of the deck names corresponding to the subprogram names is given in the table at the end of the section.



* For the FUNCTION subprograms included with each version see Section 3.4

\# Dynamics version only

Figure 3A.

TABLE OF SUBROUTINE NAMES AND DECK NAMES

Subroutine Name	Static Deck	Dynamics Deck
DATLNK	DLNK	DLKDY
GEOM	GMTRY	GMYD
DATLYR	STIFF	STFDY
DATLD	LOAD	DLDY
PANDX	PEANDX	PXDYN
RSLT	BNDRY	BNDD
FGHPE	FGMTX	FGHDY
DYLMN		LMNDY
GMTX		GDYN
ZMTRX	SOLTN	SLND
SUMS	SUSM	SUMD

The $IBJOB, $ORIGIN and $DATA cards are single control cards. The circled number found on the first two mentioned control cards, indicate the order in which they, plus the associated decks of that link, should be stacked. For example, those second level subroutines preceded by a $ORIGIN DELTA card - GEOM, DATLYR and DATLD 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 deck as shown. Since only one link of the same level may occupy core at a given time, the utility subprograms CODIMA, ENTERP and DINTRP are stored with the DATLNK link so that they may be shared by GEOM, DATLYR and DATLD.

Additional control cards preceding the $IBJOB card are likely to vary somewhat with the installation. An IBM systems handbook should be consulted. The cards used at Space and Information Systems Division are shown in Figure 3B, below.

```
9 020020 0  $JOB    IBJOB     055705055945  32  192120BB04702FURU IKE

9 020021 0  $IBJOB  PLASTIC
9 020323 0  $IBSYS
```

Figure 3B

3.3 DATA DECK SET-UP

Data decks should be stacked as follows:

1. Three cards (72 columns each) of title data.

2. GDA, general shell data, read by the EXECUTIVE program.

3. GMDA, geometry data, read by the GEØM subroutine.

All other parameters such as stiffnesses, springs, damping, mass, temperature and pressure loadings, and section properties used in stress computations are defined by function subprograms. These subprograms will be written by the user and compiled for each particular run. A discussion of how to write the various function subprograms is found in Section 3.4.

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, since this data is read by the DECRD subroutine. See Section 3.5.1. In the instructions below, the DECRD index of each input quantity is given.

3.3.1 Title Cards

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 may occur for a multiple case run in which title cards are present for the second case, or the job may terminate with an EXECUTIØN ENDED designation (as explained in Section 3.5.1). A more serious situation occurs when the data from subsequent subroutines are read out of turn and the program is placed in an endless loop.

3.3.2 GDA, General Shell Data

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).

DECRD Index	Name	Description and Comments
1	A0	Reference length (a)
2	H0	Reference thickness (h_o)
3	E0	Reference Young's modulus (E_o)
4	SIG0	Reference stress (σ_o)
5	PØI	Poisson's ratio (ν)
6	ENF	The number of Fourier components (10 maximum)

DECRD Index	Name	Description and Comments
7	BCIT	Boundary condition indicator at first station. = 1. closed apex = 2. pinned = 3. clamped = 4. free = 5. roller w = 6. roller u = 10. special boundary matrices read in with geometry data. Must use 10 whenever non-zero values are prescribed in boundary matrices ℓ_o or ℓ_n.
8	BCIB	Boundary condition indicator at last station. (As BCIT)
9	PFLAG	Print indicator for input data. = 0. prints general data and boundary matrices ≥ 1. prints above information and input data for the particular geometry configuration selected by GIN and the computed values for r, x, ω_θ, ω_ϕ, ρ and γ. = -1. prints all of above information and stiffness coefficients, elastic coefficients, thermal load and moment and pressure loads.
10	CEXT	Number of time cycles
11	DELT	Time increment in seconds

DECRD Index	Name	Description and Comments
12	THT	Circumferential angle θ (degrees). Five values of THETA may be chosen. The deflections, rotations, internal loads and stresses will be printed at these values.
18	FPRNT	Fourier component print values. Three prints are permitted. Two intermediate prints of the Fourier summing are possible for checking convergence. The last FPRNT value given should be the same as the value given for ENF in the general data, i.e., GDA (6).

Note: If THT and FPRNT are not entered, the program will set THT (1) = 0.0 and FPRNT (1) = ENF.

The last card of GDA data should have a minus (-) in column 1.

3.3.3 GMDA, Geometry Data

The GMDA data array is zeroed before the data is read. This means that any data with a value = 0. need not be entered.

DECRD Index	Name	Description and Comments
1	GIN	Geometry indicator = 1. cone-cylinder = 2. sphere-toroid = ±4. discrete points
2	EN	Number of meridional stations (100 maximum)
3	ENLAY	Number of layers

When GIN = 1.0; see Section 2.5.1

4	RA1	Radial distance from axis of revolution to station 1. (L)*

---

*L - unit of length

DECRD Index	Name	Description and Comments
5	AXL	Meridional length of shell (L)
6	ANY	Angle the generator makes with the axis of revolution (degrees)

When GIN = 2.0; see Section 2.5.2

4	RC	Radius of curvature of the generator (L)
5	RØFF	Offset distance measured from axis of revolution to center of meridional curvature (L)
6	PHI0	Initial opening angle from the vertical axis (degrees)
7	PHIN	Final opening angle from the vertical axis (degrees)

When GIN = 4.0; see Section 2.5.3

8	EM	Number of RIPT's given (12 minimum, 100 maximum)
9	RIPT	Discrete radial distances
109	XIPT	Discrete axial or vertical distances (or arc lengths)
209	RCURV	Meridional radii of curvature
309	RCURZ	Circumferential radii of curvature

Boundary matrices, when not set by indicator: only the elements which might possibly be non-zero are included in the arrays. The explanation below assumes the user is familiar with Section 2.8, Boundary Conditions.

409	BNDTX (1) = $\Omega(1,1)$	Elements of force boundary matrix (Ω_0) at station 1
410	$\Omega(1,2)$	
411	$\Omega(2,2)$	
412	$\Omega(3,3)$	

DECRD Index	Name	Description and Comments
413	$\Omega(4. 4)$	
414	$\Omega(5, 4)$	
415	$\Omega(5, 5)$	
416	BNDTX (8) = $\Lambda(1, 1)$	Elements of displacement boundary matrix (Λ_o) at station 1
417	$\Lambda(2, 2)$	
418	$\Lambda(3, 3)$	
419	$\Lambda(4, 4)$	
420	$\Lambda(5, 5)$	
421	BNDTX (13) = ℓ_1	Column boundary matrix (ℓ) at station 1. The five elements are in consecutive locations.
426	BNDTB (1) = $\Omega(1, 1)$	Elements of force boundary matrix (Ω_N) at station N, stored in the same manner as Ω_o above.
433	BNDTB (8) = $\Lambda(1, 1)$	Elements of displacement boundary matrix (Λ_N) at station N; diagonal elements only.
438	BNDTB (13) = ℓ_1	Matrix (ℓ) for the last station

The last card of GMDA data should have a minus (-) in column 1.

3.4 FUNCTIONAL SUBPROGRAMS

The FUNCTION subprogram is an independently written and compiled program that is executed wherever its name appears in an arithmetic statement in another routine. The object (binary) or source (FORTRAN) deck must be included in the job deck even though the FUNCTION value equals zero; otherwise, the program that references the FUNCTION will not be executed.

Since a FUNCTION is a separately compiled subprogram, the variables and statement numbers within it do not relate to any other component of the program. Communication between the FUNCTION and its calling program takes place at execution time. The value of the FUNCTION is always returned to the calling program; values may also be returned via the FUNCTION arguments and/or variables assigned to a common region.

General Form:

```
FUNCTION      name (a, b, ... n)
     .
     .
     .
name = ...
     .
     .
     .
RETURN
     .
     .
     .
END
```

Name is a subprogram name (1-6 alphanumeric characters, the first of which is alphabetic). FUNCTION names used in this program are listed at the end of this section.

a, b, --n are nonsubscripted variable or array names used to transfer values between the FUNCTION subprogram and the program that references it. There must be at least one argument.

Basic Description:

The FUNCTION statement must be the first statement in the subprogram definition. (Comments cards excluded.) The name must not be the same as a library or built-in function unless the name is included in an EXTERNAL statement which precedes the first use of the FUNCTION by the calling program.

The FUNCTION subprogram may contain any FORTRAN statement except another FUNCTION statement, a SUBROUTINE statement, or a BLOCK DATA subprogram.

A variable in a COMMON block may be referenced if the rules for use of COMMON are followed.

The name of the FUNCTION must be assigned a value at least once within the subprogram. This value may be assigned by the appearance of the function name on the left side of an arithmetic statement (e.g. SOMEF = X/Y), or by its appearance in the list of a READ statement within the subprogram.

Arguments:

The relationship between variable names used as arguments in the calling program and the variables used as arguments in the FUNCTION subprogram is illustrated in the following example.

Calling Program

```
           .
           .
           .
    A = SOMEF (B, C)
           .
           .
           .
```

Subprogram

```
      FUNCTION SOMEF (X, Y)
50 SOMEF = X/Y
55 RETURN
      END
```

The value of the variable B of the calling program will be used as the value of the subprogram variable X; and C for Y. Thus, if B = 10.0 and C = 5.0, then A = 2.0.

The arguments used in the unsymmetrical shell of revolution program are PEL, ZTA and TU, where PEL is the meridional distance to a station, ZTA is the circumferential distance and TU is the elapsed time. If additional values are necessary to define a FUNCTION it will be necessary to include a READ statement in the subprogram and to supply the required data cards to satisfy the READ at execution time.

RETURN and END Statements:

A FUNCTION subprogram must contain an END statement and at least one RETURN statement. The END statement specifies the physical end of the subprogram for the compiler. The RETURN statement signifies a logical conclusion of the computation and returns any computed value and control to the calling program.

Multiple Entries:

The normal entry into a FUNCTION subprogram is made by a function reference in an arithmetic expression. Entry is made at the first executable statement following the FUNCTION statement. It is also possible to enter a FUNCTION by means of a reference to an ENTRY statement in the FUNCTION.

General Form

```
ENTRY    name (a, b, ... n)
```

name is the name of an entry point. It must follow all the rules given for the FUNCTION name.

a, b, ... n are the dummy arguments corresponding to actual arguments supplied by a function reference.

The ENTRY statement is not executable. When inserted in a series of statements, the ENTRY statement has no effect on the logical flow of the subprogram. Entry to the subprogram is made at the first executable statement following the ENTRY statement, so it is easy to start using a subprogram at any desired point.

Within a FUNCTION subprogram, only the FUNCTION name may be used as the variable to carry a result back to the calling program. The ENTRY name may not be used for this purpose. The following example illustrates this rule.

Calling Program

```
      •
      •
      •
A = ONEF (B, C)
      •
      •
      •
F = TWOF (D, E)
      •
      •
      •
```

Subprogram

```
     FUNCTION ONEF (X, Y)
5 ONEF = X * Y
10 RETURN
```

```
      ENTRY TWOF (X, Y)
 →    ONEF = X + Y
20 RETURN
      END
```

Note the use of the primary function name to return the function value to the calling program, even when the reference was to an ENTRY name.

Additional examples showing the use of FUNCTION subprograms with multiple ENTRY statements may be found in Sections 3.6, 3.7, 3.8 and 3.9.

Following is a table which gives the FUNCTION names, ENTRY names, calling program names and the assigned deck names ($ IBFTC manes) for the static and dynamic versions of the Unsymmetrical Shell of Revolution Program. For their definitions see Program Nomenclature, Section 3.13.

	STATIC	DYNAMIC
Calling Program DATLYR		
FUNCTION BBB (PEL, ZTA) ENTRY DDD (ZTA)	BFCN	DBBDD
FUNCTION ENTT (PEL, ZTA) ENTRY EMTT (PEL, ZTA)	TFCN	DTMP
FUNCTION *DKK1 (PEL, ZTA) ENTRY *DKK2 (PEL, ZTA) ENTRY DKK3 (PEL, ZTA)	KFCN	DKDMP
ENTRY DMP1 (PEL, ZTA) ENTRY DMP2 (PEL, ZTA) ENTRY DMP3 (PEL, ZTA)		
FUNCTION DMM1 (PEL, ZTA) ENTRY DMM4 (PEL, ZTA)		DMASS
Calling Program DATLD		
FUNCTION PPPN (PEL, ZTA) ENTRY PPPH (PEL, ZTA) ENTRY PPPF (PEL, ZTA)	PFCN	

*Deleted in the static deck because of core storage problems, therefore DKK3 becomes the FUNCTION name.

```
                                           STATIC    DYNAMIC

    FUNCTION  PPPN (PEL, ZTA, TU)
       ENTRY  PPPH (PEL, ZTA, TU)                    DPRSS
       ENTRY  PPPF (PEL, ZTA, TU)

Calling Program SUMS

    FUNCTION  EI1 (PEL, ZTA)
       ENTRY  DN1 (PEL, ZTA)               STR1FN
       ENTRY  POIS1 (PEL, ZTA)

    FUNCTION  EI2 (PEL, ZTA)
       ENTRY  DN2 (PEL, ZTA)               STR2FN
       ENTRY  POIS2 (PEL, ZTA)

    FUNCTION  TMP1 (PEL, ZTA)
       ENTRY  ALF1 (PEL, ZTA)              TTF1

    FUNCTION  TMP2 (PEL, ZTA)
       ENTRY  ALF2 (PEL, ZTA)              TTF2
```

3.5 UTILITY SUBROUTINES

3.5.1 DECRD Subroutine

All data, with the exception of the three title cards, is read by means of the DECRD subroutine, included with the symbolic decks.

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 either in sequential or in 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 16th 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 3.6.2 have 6 fields of 12 card columns each, and an identification field of 8 columns for sorting purposes.

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 print-out of the columns 1-80 of the defective card. The job will be terminated.

If the data for the array in the CALL statement has been completely read, and no negative sign has been encountered in column 1 of the last card sent, 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 EXECUTION ENDED designation.

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.

In order to use the DECRD routine in conjunction with the ALTIO option, it is necessary to physically load a copy of the routine with the program deck. ALTIO will not cause the proper adjustments to DECRD from the library tape at load time, so drop-in decks must be used.

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
$IBFTC DECRD
      SUBROUTINE DECRD(D)
      DIMENSION  FLT(5), ID(2), D(1)
   10 READ (5,100) LOC, FLT, ID
  100 FORMAT (I12, 5F12.0, 1A6, 1A2)
      IF (LOC .EQ. 0)   GO TO 500
   15 K = IABS(LOC) - 1
      DO 20 I = 1,5
      IF (SIGN(1.0,FLT(I)).LT.0.0 .AND. FLT(I) .EQ. 0.0)  GO TO 20
      J = K + I
      D(J) = FLT(I)
   20 CONTINUE
      IF (LOC .LT. 0)  GO TO 1000
      GO TO 10
  500 WRITE (6,200) ID
  200  FORMAT(10H0BAD DATA 1A6,1A2)
      CALL EXIT
 1000 RETURN
      END
```

3.5.2 MAD, MSU, MMY, INVMS

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 in the 1st three routines other than the usual NAASYS trapping information for underflows, overflows and divide checks. When data has been entered correctly, these subroutines will present no problems.

The inversion routine has an error indicator, IX, which is set at 0 or -1 for a singular matrix. This is returned to the calling program through the argument list and may be tested after return. The Unsymmetrical Shell of Revolution Program makes such a test, prints the comment "SINGULAR MATRIX I = XX" and terminates the job. When this error occurs, check the data—especially any special boundary matrices entered, and the FUNCTION subprograms.

The Dynamics version of the program uses a MAP (machine language coded) copy of the INVMS subroutine. The FORTRAN language routine causes the GDYN link to exceed core storage. Listings for both versions are included.

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```
$IBFTC MADD
C     MATRIX ADD SUBROUTINE                                 DECK NO• 8K-903    00000400
C                                                                              00000410
C   ARGUMENTS                                                                  00000420
C     L   NO• OF ROWS                                                          00000430
C     M   NO• OF COLS                                                          00000440
C     A(I•J)      MRA                                                          00000450
C     B(I•J)      MAD                                                          00000460
C     C(I•J)      MSR                                                          00000470
      SUBROUTINE MAD(L•M•A•B•C)                                                00000480
      DIMENSION A(50•50)• B(50•50)• C(  •50)                                   00000490
      DO 30 I=1•L                                                              00000500
      DO 30 J=1•M                                                              00000510
   30 C(I•J)=A(I•J)+B(I•J)                                                     00000520
      RETURN                                                                   00000530
      END
```

```
$IBFTC MSUB
C     MATRIX SUBTRACT SUBROUTINE                        DECK NO. 8K-904 00000400
C                                                                       00000410
C  ARGUMENTS                                                            00000420
C     L  NO. OF ROWS                                                    00000430
C     M  NO. OF COLS                                                    00000440
C     A(I,J)   MRA                                                      00000450
C     B(I,J)   MSU                                                      00000460
C     C(I,J)   MSR                                                      00000470
      SUBROUTINE MSU(L,M,A,B,C)                                         00000480
      DIMENSION A(50,50), B(50,50), C(50,50)                            00000490
      DO 30 I=1,L                                                       00000500
      DO 30 J=1,M                                                       00000510
   30 C(I,J)=A(I,J)-B(I,J)                                              00000520
      RETURN                                                            00000530
      END
```

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```
$IBFTC MMPY
C     MATRIX MULTIPLY SUBROUTINE                                        DECK NO. 8K-901   00000010
C                                                                                         00000020
C   ARGUMENTS                                                                             00000030
C     L   NO. OF ROWS X MATRIX                                                            00000040
C     M   NO. OF COLS X MATRIX                                                            00000050
C     N   NO. OF COLS Y MATRIX                                                            00000060
C     X(I,K)    MRA                                                                       00000070
C     Y(K,J)    MMY                                                                       00000080
C     Z(I,J)    MSP                                                                       00000090
      SUBROUTINE MMY(L,M,N,X,Y,Z)                                                         00000100
      DIMENSION X(50,50), Y(50,50), Z(50,50)                                              00000110
      DO 30 I=1,L                                                                         00000120
      DO 30 J=1,N                                                                         00000130
      Z(I,J)=0.0                                                                          00000140
      DO 30 K=1,M                                                                         00000150
   30 Z(I,J)=Z(I,J)+X(I,K)*Y(K,J)                                                         00000160
      RETURN                                                                              00000170
      END
```

```
$IBFTC INVNSP                                                           INVS0000
C   ***  7094 FORTRAN IV SINGLE PRECISION GENERAL DIMENSION FIND INVERSEINVS0001
C OF MATRIX USING SINGLE PRECISION OPERATIONS                           INVS0002
C                                                                       INVS0003
C ARGUMENTS                                                             INVS0004
C  A  ORIGINAL MATRIX DIMENSIONED N X N                                 INVS0005
C  N  ROW DIMENSION OF A AND AI AS GIVEN BY DIMENSION STATEMENT         INVS0006
C  M1 NUMBER OF ROWS USED BY A AND AI M1 MUST BE LESS THAN OR EQUAL TO NINVS0007
C  IX ERROR INDICATOR                                                   INVS0008
C  D  WORKING ARRAY MUST BE SINGLE PRECISION AND DIMENSIONED M1 X M1    INVS0009
C                                                                       INVS0010
      SUBROUTINE INVMS  (A,N,M1,IX,D,AI)                                INVS0011
C                                                                       INVS0012
      DIMENSION  A(N,1), D(M1,1), IKOL(50), AI(N)                       INVS0020
      REAL      MULT                                                    INVS0030
      EQUIVALENCE  (I1,I4,I7   ),  (I2,I5,J,K),  (I3,L),                INVS0040
     1   (PROD,MULT,AMX)                                                INVS0050
C                                                                       INVS0059
       M  =  M1                                                         INVS0060
        DO    3  I=1,M                                                  INVS0070
        DO    3  J=1,M                                                  INVS0080
    3   D(I,J)  =  A(I,J)                                               INVS0090
C                                                                       INVS0099
       DO 1000   I=1,M                                                  INVS0100
        I1  =  I                                                        INVS0110
        DO 5  J=1,M                                                     INVS0120
    5      AI(J)     =    ABS(D(I,J))                                   INVS0130
            IF (I1 - 1)      6,11,6                                     INVS0140
    6       DO 10  I2=2,I1                                              INVS0150
                I3  =  IKOL(I2-1)                                       INVS0160
   10        AI(I3)    =  0.                                            INVS0170
   11 CONTINUE                                                          INVS0180
      AMX  = AI(1)                                                      INVS0190
      I4  =  1                                                          INVS0200
          DO 15  I5=2,M                                                 INVS0210
             IF(AI(I5)   .LE. AMX)     GO TO 15                         INVS0220
            AMX  = AI(I5)                                               INVS0230
            I4  =  I5                                                   INVS0240
   15       CONTINUE                                                    INVS0250
         IKOL(I)  =  I4                                                 INVS0260
         PROD  =  D(I,I4)                                               INVS0270
      AT       =      1.                                                INVS0280
      IF  (A(I,I4) .EQ. 0.)      GO TO 17                               INVS0290
```

112

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```
      AT    =  ABS(PROD / A(I,I4))                                        INVS0300
   17 IF  (I .EQ. 1)                    AMN   =  1.                       INVS0310
      AMN  =    AMIN1 (AT,AMN)                                            INVS0320
        D(I,I4)  =  1.                                                    INVS0330
         IF (PROD)   20,2000,20                                           INVS0340
   20          DO 30 K=1,M                                                INVS0350
   30          D(I,K)  =  D(I,K) / PROD                                   INVS0360
               DO 40 L=1,M                                                INVS0370
               IF (L .EQ. I)   GO TO 40                                   INVS0380
               MULT  =  D(L,I4)                                           INVS0390
               D(L,I4)  =  0.                                             INVS0400
                    DO 35 K=1,M                                           INVS0410
   35               D(L,K)  =  D(L,K) - MULT * D(I,K)                     INVS0420
   40          CONTINUE                                                   INVS0430
 1000   CONTINUE                                                          INVS0440
C                                                                         INVS0449
      DO 1015 I=1,M                                                       INVS0450
        I7 = IKOL(I)                                                      INVS0460
          DO 1010 J=1,M                                                   INVS0470
        I8 = IKOL(J)                                                      INVS0480
 1010   A (I7,J)   =    D(I,I8)                                           INVS0490
 1015    CONTINUE                                                         INVS0500
C                                                                         INVS0509
      IX  =  1                                                            INVS0510
      AMN  =  ALOG10 (1./AMN)                                             INVS0520
      IF (AMN .GT. 6.)    IX  =  -1                                       INVS0530
 1030 D(1,1)  =  AMN                                                      INVS0540
      RETURN                                                              INVS0550
 2000 IX  =  0                                                            INVS0560
      GO TO 1030                                                          INVS0570
      END                                                                 INVS0580
```

```
$IBMAP INVMS                                                            30710000
       LBL       INVMS,                                                 30710010
INVS   CLA*      5,4                                                    30710020
       SXA       EX1,1                                                  30710030
       SXA       EX2,2                                                  30710040
       SXA       EX3,3                                                  30710050
       STA       N1                                                     30710060
       STA       N3                                                     30710070
       STA       N4                                                     30710080
       STA       N6                                                     30710090
       STA       N7                                                     30710100
       STA       N10                                                    30710110
       STA       N13                                                    30710120
       STA       N14                                                    30710130
       STA       FIN                                                    30710140
       PAC       ,1                                                     30710150
       SCD       N12,1                                                  30710160
       SXD       MN,1                                                   30710170
       ADD       ROWTA                                                  30710180
       STA       R1                                                     30710190
       STA       R2                                                     30710200
       STA       R3                                                     30710210
       STA       R4                                                     30710220
       CLA*      4,4                                                    30710230
       STO       N                                                      30710240
       PAX       ,1                                                     30710250
       SXD       N2,1                                                   30710260
       SXD       N5,1                                                   30710270
       SXD       N8,1                                                   30710280
       SXD       N9,1                                                   30710290
       SXD       N11,1                                                  30710300
       LDQ*      5,4                                                    30710310
       MPY       N                                                      30710320
       XCA                                                              30710330
       SUB       N                                                      30710340
       SUB       =1                                                     30710350
       ADD       3,4                                                    30710360
       STA       MX1         (MX+N**2-N-1)                              30710370
       STA       MX2                                                    30710380
       STA       MX3                                                    30710390
       STA       MX4                                                    30710400
       STA       MX5                                                    30710410
       STA       MX6                                                    30710420
```

114

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```
         CLA     3,4                                         307I0430
         STA     H+1                                         307I0440
         SUB     =1                                          307I0450
         STA     ST1                                         307I0460
         AXC     1,2          (-I)                           307I0470
         SXD     X1,2                                        307I0480
SEARCH   SXA     S2,2                                        307I0490
         SXD     ROWNI+1,2                                   307I0500
         TXI     *+1,2,-1                                    307I0510
         SXD     ROWNI+2,2                                   307I0520
         TXI     *+1,2,1                                     307I0530
N1       AXT     **,3                                        307I0540
MX1      CLA     **,2                                        307I0550
R1       SLW     **,3                                        307I0560
N2       TXI     *+1,2,**            (N)                     307I0570
         TIX     MX1,3,1                                     307I0580
         AXC     1,3                                         307I0590
X1       TXH     *+2,3,** (-M-1)                             307I0600
         TRA     N3                                          307I0610
         CLA     COLNOS-1,3                                  307I0620
         PAX     ,2                                          307I0630
R2       STZ     **,2                                        307I0640
         TIX     X1,3,1                                      307I0650
N3       AXT     **,3                (N)                     307I0660
         SXA     J,3                                         307I0670
R3       CLA     **,3                                        307I0680
X3       TIX     R4,3,1                                      307I0690
         TRA     X5                                          307I0700
R4       CAS     **,3                                        307I0710
         TRA     X3                                          307I0720
         TRA     X3                                          307I0730
         SXA     J,3                                         307I0740
         TRA     R3                                          307I0750
X5       LXD     X1,3                                        307I0760
         TXI     *+1,3,-1                                    307I0770
         SXD     X1,3                                        307I0780
         CLA     J                                           307I0790
         STO     COLNOS-2,3                                  307I0800
S2       AXT     **,2                                        307I0810
         LDQ     J                                           307I0820
         MPY     N                                           307I0830
         XCA                                                 307I0840
         SUB     N                                           307I0850
```

```
        SUB     =1                                              307I0860
        ADD     3,4                                             307I0870
        STA     J1                                              307I0880
        STA     J2                                              307I0890
        STA     J3                                              307I0900
        STA     J4                                              307I0910
J1      CLA     **,2                                            307I0920
        TZE     SING                                            307I0930
        STO     PROD                                            307I0940
        CLA     =1.                                             307I0950
J2      STO     **,2                                            307I0960
N4      AXT     **,3                                            307I0970
MX2     NULL                                                    307I0980
ROWI    CLA     **,2                                            307I0990
        FDP     PROD                                            307I1000
MX3     NULL                                                    307I1010
        STQ     **,2                                            307I1020
N5      TXI     *+1,2,**                                        307I1030
        TIX     ROWI,3,1                                        307I1040
N6      AXC     **,1                                            307I1050
ROWNI   SXA     S1,1                                            307I1060
        TXH     *+2,1,**                                        307I1070
        TXH     S1+1,1,**                                       307I1080
J3      CLA     **,1                                            307I1090
        STO     MULT                                            307I1100
J4      STZ     **,1                                            307I1110
N7      AXT     **,3                                            307I1120
        XEC     S2                                              307I1130
MX4     LDQ     **,2                                            307I1140
        FMP     MULT                                            307I1150
        STO     TEMP                                            307I1160
MX5     CLA     **,1                                            307I1170
        FSB     TEMP                                            307I1180
MX6     STO     **,1                                            307I1190
N8      TXI     *+1,2,**                                        307I1200
N9      TXI     *+1,1,**                                        307I1210
        TIX     MX4,3,1                                         307I1220
S1      AXT     **,1                                            307I1230
        TXH     *+2,1,-2                                        307I1240
        TXI     ROWNI,1,1                                       307I1250
        XEC     S2                                              307I1260
MN      TXL     FIN,2,**          (-N)                          307I1270
        TIX     SEARCH,2,1                                      307I1280
```

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```
FIN     AXC     **,1                                                    307I1290
ST2     SXA     SAV1,1                                                  307I1300
        CLA     COLNOS-1,1                                              307I1310
        PAC     ,2                                                      307I1320
N10     AXT     **,3                                                    307I1330
ST1     CLA     **,1                MX-1                                307I1340
DUM1    STO     TOL-1,2             DUMY-1                              307I1350
N11     TIX     *+1,1,**            N                                   307I1360
N12     TIX     *+1,2,**            N                                   307I1370
        TIX     ST1,3,1                                                 307I1380
SAV1    AXT     **,1                RESTORE   (-1)                      307I1390
        TXH     *+2,1,-2                                                307I1400
        TXI     ST2,1,1                                                 307I1410
N13     AXC     **,1                N                                   307I1420
H2      SXA     H1,1                                                    307I1430
        LDQ     COLNOS-1,1                                              307I1440
        MPY*    5,4                                                     307I1450
        XCA                                                             307I1460
        SUB*    5,4                                                     307I1470
        PAC     ,2                  (-J)                                307I1480
        PCA     ,1                                                      307I1490
        XCA                                                             307I1500
        MPY     N                                                       307I1510
        XCA                                                             307I1520
        SUB     N                                                       307I1530
        PAC     ,1                                                      307I1540
N14     AXT     **,3                N                                   307I1550
H       CLA     TOL,2               DUMY                                307I1560
        STO     **,1                MX                                  307I1570
        TXI     *+1,1,-1                                                307I1580
        TXI     *+1,2,-1                                                307I1590
        TIX     H,3,1                                                   307I1600
H1      AXT     **,1                RESTORE   (-1)                      307I1610
        TXH     *+2,1,-2                                                307I1620
        TXI     H2,1,1                                                  307I1630
        CLA     =1                                                      307I1640
IXSTO   STO*    6,4                                                     307I1650
EX1     AXT     **,1                                                    307I1660
EX2     AXT     **,2                                                    307I1670
EX3     AXT     **,3                                                    307I1680
        TRA     1,4                                                     307I1690
SING    STZ*    6,4                                                     307I1700
        TRA     EX1                                                     307I1710
```

```
        REM     STORAGF          1                                  307I1720
N       PZE                      1                                  307I1730
J       PZE                                                         307I1740
TOL     FQU     BLK1                                                307I1750
COLNOS  EQU     BLK2                                                307I1760
DUMY    EQU     TOL              N**2                               307I1770
TEMP    EQU     DUMY+2                                              307I1780
MULT    EQU     DUMY+3                                              307I1790
ROWTAB  EQU     DUMY+4                                              307I1800
PROD    EQU     MULT             1                                  307I1810
ROWTA   CLA     ROWTAB                                              307I1820
        FND                                                         307I1830
```

3.5.3 DINTRP, ENTERP

These subroutines perform linear double and single interpolation. DINTRP makes use of ENTERP in interpolation for values along a particular curve. They are included for use by FUNCTION subprograms called by DATLYR or DATLD.

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.

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```
$IBFTC ENTP
C     LINEAR  INTERPOLATION  SUBROUTINE **ENTERP**             6J-997        00000001
C                                                                           00000002
C     SELECTS THE VALUF AT FITHER END OF TABLE WHFN ARGUMENT EXCEFDS        00000003
C     LIMIT, THEN CONTINUES                                                 00000004
C                                                                           00000005
C  SUBROUTINE ARGUMENTS                                                     00000006
C     X           VALUE TO LOOK UP IN TABLE                                 00000007
C     TAB(1)      NO. OF PAIRS OF ARGUMENTS AND VALUES IN TABLE             00000008
C     TAB(2),ETC ARGUMENTS AND FUNCTIONS INTERLACED                         00000009
C                                                                           00000019
      FUNCTION ENTERP (X,TAB)                                               00000020
C                                                                           00000024
      DIMENSION TAB(101)                                                    00000025
      IF (TAB) 9,9,8                                                        00000030
    9 ENTERP = - TAB                                                        00000035
      RETURN                                                                00000040
    8 N = TAB                                                               00000045
      DO 5 I=1,N                                                            00000050
    1 IF (TAB(2*I)-X) 5,4,3                                                 00000055
    3 IF (I-1) 6,6,7                                                        00000060
    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))                                         00000070
      RETURN                                                                00000080
    4 ENTERP = TAB(2*I+1)                                                   00000085
      RETURN                                                                00000090
    5 CONTINUE                                                              00000095
      M = 2*N+1                                                             00000100
      K = M                                                                 00000101
  105 WRITE  ( 6,10)   X, TAB(K)                                            00000105
   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)                                                       00000115
      RETURN                                                                00000120
    6 M = 2*N+1                                                             00000130
      K = 3                                                                 00000140
      GO TO 105                                                             00000150
      END                                                                   00000160
```

```
$IBFTC DNTP
C     DOUBLE INTERPOLATION FUNCTION SUBROUTINE             J.L. FICK      00000001
C   ARGUMENTS                                                             00000002
C     X     USED TO DETERMINE WHICH TABLE TO USE (WHICH CURVE OF FAMILY)00000003
C     Y     ARGUMENT USED AS X COORDINATE OF POINTS ON CURVE              00000004
C     TAB(1)      NO. OF TABLES (NO. OF CURVES IN FAMILY)                 00000005
C     TAB(2)      NO. TO REPRESENT FIRST CURVE. MUST BE ITS LOWEST VALUE 00000006
C     TAB(3)      NO. OF ARGUMENTS IN FIRST TABLE (POINTS ALONG CURVE)    00000007
C     TAB(4),ETC.     X AND Y VALUES ALONG CURVE (INTERLACED)             00000008
C     TAB(2*TAB(3)+4)      LIKE TAB(2) FOR 2ND CURVE.  THIS IS FOLLOWED  00000009
C     BY ITS NO. OF PTS., VALUES, AND REPEATED THE NO. OF TIMES NECES-   00000010
C     SARY BASED ON THE NO. OF TABLES LISTED IN TAB(1)                    00000011
C                                                                         00000012
      FUNCTION DINTRP(X,Y,TAB)                                            00000020
      DIMENSION TAB(1)                                                    00000025
      N = TAB + .5                                                        00000030
      J = 0                                                               00000035
      K = 0                                                               00000040
    3 DO 50 I=1,N                                                         00000045
C     M SELECTS ONE OF FAMILY OF CURVES EQUAL TO OR ABOVE X VALUE   .     00000049
      M = I+J                                                             00000050
C     MU REPRESENTS NEXT LOWEST CURVE IN FAMILY                           00000054
      MU = I+K-1                                                          00000055
      IF(TAB(M+1)-X) 20,10,4                                              00000060
    4 IF(I-1) 5,5,7                                                       00000065
   10 DINTRP=ENTERP(Y,TAB(M+2))                                           00000070
      RETURN                                                              00000075
    7 Z2 = ENTERP(Y,TAB(M+2))                                             00000080
      Z1 = ENTERP(Y,TAB(MU+2))                                            00000085
      DINTRP = Z1 + (X - TAB(MU+1)) * (Z2 - Z1) / (TAB(M+1) - TAB(MU+1))00000090
      RETURN                                                              00000095
   20 K = J                                                               00000100
   50 J =  INT (TAB(M+2) + .5) * 2 + 1 + J                                00000105
    5 MP1 = M + 1                                                         00000110
    6 WRITE (6, 30)  X, (TAB(L), L=1,MP1)                                 00000115
   30 FORMAT(//5X, 43HARGUMENT EXCEEDS EXTENT OF TABLE IN DINTRP. /10X, 00000116
     1 10HARGUMENT =,1PE12.4 /10X, 12HTABLE VALUES, 5X,1P6E12.4 /         00000117
     2   (27X, 6E12.4) )                                                  00000118
      CALL EXIT                                                           00000120
      STOP                                                                00000125
      END                                                                 00000140
$*
```

3.5.4 CODIMA

CODIMA is a curve fitting subroutine which 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 such 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 sense that:

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 a way such that the polynomial that deviates less from the straight line connecting the points defining the interval is given more weight. For simplicity, parabolae are used over higher degree polynomials, in the CODIMA version.

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```
$IBFTC CODS                                                             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
```

```
  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
```

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```
  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
```

3.5.5 FILE

FILE is a function subprogram by which any number of files (or end of file-marks) on a tape may be skipped, as specified by the programmer. Alternatively, the tape may be backspaced any number of files. The tape is positioned at the beginning of the desired file ready to read or write the first record. (Extent: 45 locations.)

Availability: On the FORTRAN library tape.

Use: The specified tape can be positioned as indicated by means of the statement:

A = FILE(I, J)

A	Used to make the statement format consistent with FORTRAN rules.
I	FORTRAN tape number of one of the available tapes; must be a positive fixed point constant or variable.
J	The number of files to be skipped or backspaced, including the file in which the tape is positioned. It must be a fixed point FORTRAN expression. J > O, skip J < O, backspace J should never be zero. If a zero argument is used, one file will be skipped either forward or backward depending on the sign of zero.

Examples:

a. Tape 4 is positioned within or at the end of file 2 and we wish to get to file 5. Then J = 3.

   A = FILE(4, 3)

b. Tape 4 is positioned at the beginning of file 12 and file 16 is desired. Then J = 4.

   A = FILE(4, 4)

c. Tape 4 is positioned anywhere within file 7 and file 4 is desired. Then J = -4.

   A = FILE(4, -4)

d. Tape 4 is positioned anywhere within file 7 and the beginning of file 7 is desired. Then J = -1.

   A = FILE(4, -1)

   Even if the tape is at the beginning of a file, you must count that file in computing the value of J. In the last example, if tape 4 is at the beginning of file 7 and a J of -1 is given, the next file to be read or written would still be file 7.

```
$IBMAP FILF.Q                                                           N5250000
       TITLF                                                            N5250010
       LBL     FILE,BFGIN,                                              N5250020
************************************************************************N5250030
*                                                                       N5250040
*      ROUTINF TO POSITION A FORTRAN TAPE AT THE BEGINNING OF A FILE.   N5250050
*                                                                       N5250060
*      CALL    FILF(UNIT,COUNT)                                         N5250070
*                                                                       N5250080
*      UNIT    = FORTRAN TAPE NUMBER. (INTEGER)                         N5250090
*              UNIT MUST BE A 729 TAPE.                                 N5250100
*              UNIT MUST BE A SCRATCH OR RESERVE TAPE.                  N5250110
*                                                                       N5250120
*      COUNT   = NUMBER OF FILES TO RF SKIPPFD OR BACKSPACED,           N5250130
*              INCLUDING THF CURRENT FILE. (INTEGER)                    N5250140
*              COUNT GT 0 MFANS SKIP.                                   N5250150
*              COUNT LT 0 MFANS BACKSPACE.                              N5250160
*              COUNT EQ 0 MFANS NO OPERATION.                           N5250170
*                                                                       N5250180
*      ORIGINAL PROGRAMMING BY E. LESTER, 892 G.O., 7/10/63             N5250190
*      REVISED BY H. HARNED, I.B.M.                                     N5250200
*      REWRITTEN BY D. H. ADAMS, 200-312 S.I.D., 8/13/65                N5250210
*                                                                       N5250220
************************************************************************N5250230
       TTL     PARAMETER DEFINITIONS                                    N5250240
UNIT   SET     1+2                     (ARG) FORTRAN UNIT               N5250250
COUNT  SET     2+2                     (ARG) FILE COUNT (+ OR -)        N5250260
       SPACE                                                            N5250270
UCW3   SET     2                       UCB WORD 3                       N5250280
FCW3   SET     2                       FCB WORD 3                       N5250290
FCW4   SET     3                       FCB WORD 4                       N5250300
FCW6   SFT     5                       FCB WORD 6                       N5250310
FCW10  SFT     9                       FCB WORD 10                      N5250320
BSF    SET     6                       BACKSPACE FILE                   N5250330
LENGTH SET     12                      FCB LENGTH                       N5250340
       SPACE                                                            N5250350
UCB    SET     4                       (XR) UNIT CONTROL BLOCK          N5250360
FCB    SET     1                       (XR) FILE CONTROL BLOCK          N5250370
NFILFS SFT     1                       (XR) FILE COUNT                  N5250380
LFB    SET     4                       (XR) LENGTH OF FILE BLOCK        N5250390
       SPACF                                                            N5250400
MONUNI LBOOL   200000                  MONITOR UNIT                     N5250410
INT    LBOOL   400000                  INTERNAL FILE                    N5250420
```

```
NON729 IBOOL   600000            DEVICE NOT 729 TAPE                N5250430
       SPACE                                                        N5250440
.CLOSE EQU     .CLSFQ            AVOID IOCS FOR ALTIO               N5250450
       SPACE                                                        N5250460
SYSUNI OCT     140               SYSTEM UNIT TABLE ORIGIN           N5250470
       TTL     INITIALIZATION                                       N5250480
FILE   SAVE    1,I                                                  N5250490
       NZT*    COUNT,4           =FILE COUNT                        N5250500
       RETURN  FILE              RETURN IF ZERO                     N5250510
       CLA*    UNIT,4            =FORTRAN UNIT                      N5250520
       TSX     .DECVA,4          CONVERT TO BCD                     N5250530
       XCL                                                          N5250540
       ANA     =07777            MODULO 100                         N5250550
       SLW     NUMBER            STORE FOR COMPARE                  N5250560
       CAL     .LFBL                                                N5250570
       PAC     ,FCB              =FILE BLOCK ORIGIN                 N5250580
       PDX     ,LFB              =FILE BLOCK LENGTH                 N5250590
*-------                         SEARCH FCB'S FOR UNIT              N5250600
SEARCH CAL     FCW10,FCB         =FILE NAME, 'UNIT**'               N5250610
       ANA     =07777            EXTRACT **                         N5250620
       LAS     NUMBER            COMPARE WITH UNIT                  N5250630
       TRA     *+2                                                  N5250640
       TRA     FOUND                                                N5250650
       TNX     NOFILE,LFB,LENGTH IS THERE ANOTHER FILE              N5250660
       TXI     SEARCH,FCB,-LENGTH YES, EXAMINE IT                   N5250670
*-------                                                            N5250680
FOUND  SCA     CLOSF,FCB         STORE LOC(FILE)                    N5250690
       SCA     NDSEL,FCB                                            N5250700
       PCA     ,FCB                                                 N5250710
       SUB     SYSUNI            DECEIVE .LXSEL                     N5250720
       STA     LXSEL                                                N5250730
       TTL     HOUSEKEEPING                                         N5250740
       TSX     .CLOSE,4          CLOSE FILE                         N5250750
CLOSE  MON     **                                                   N5250760
       SPACE                                                        N5250770
       LDI     FCW3,FCB          IS UNIT                            N5250780
       BFT     MONUNI            MONITOR CONTROLLED                 N5250790
       TRA     ERROR             YES                                N5250800
       SPACE                                                        N5250810
       LDI     FCW4,FCB          IS FILE                            N5250820
       BFT     INT               INTERNAL                           N5250830
       TRA     ERROR             YES                                N5250840
       SPACE                                                        N5250850
```

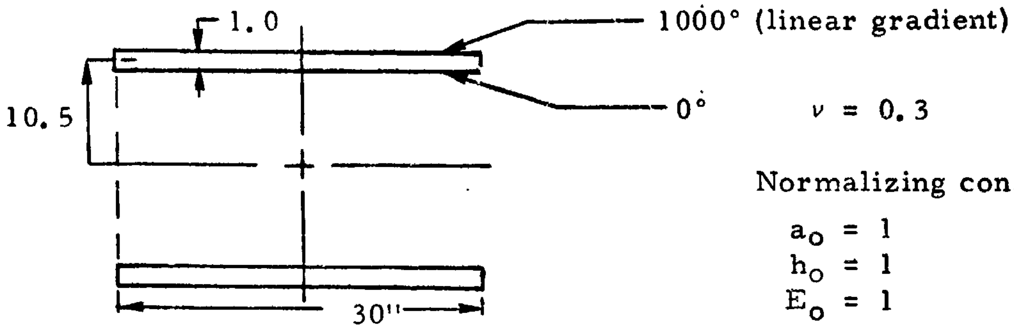
```
       LDI    FCW6,FCB             IS UNIT                          N5250860
       BFT    NON729               A 729 TAPE                       N5250870
       TRA    FRROR                NO                               N5250880
       SPACF                                                        N5250890
       LXA    LK.DR,4                                               N5250900
       CLA*   COUNT,4              =FILE COUNT                      N5250910
       PAX    ,NFILES                                               N5250920
       TPL    SKIP                 FORWARD IF PLUS, ELSE ...        N5250930
       TTL    PERFORM RFQUESTED ACTION                              N5250940
       TSX    .NDSFL,4             BACKSPACE 1 FILE                 N5250950
NDSEL  PZE    **,,BSF                                               N5250960
       TIX    *-2,NFILES,1         COUNT DOWN                       N5250970
       SPACE                                                        N5250980
       CLA*   NDSEL                FXAMINF TAPE POSITION --         N5250990
       PAC    ,UCB                 IF NOT AT LOAD POINT             N5251000
       NZT    UCW3,UCB             THEN READ PAST EOF               N5251010
       RETURN FILE                 FLSE RETURN                      N5251020
       SPACE                                                        N5251030
SKIP   CALL   .LXSEL(LXSEL)        SKIP 1 FILE                      N5251040
       TIX    SKIP,NFILES,1        COUNT DOWN                       N5251050
       RETURN FILF                                                  N5251060
       SPACE  4                                                     N5251070
LXSEL  PON    **,,*+1                                               N5251080
       IORPN  ,,0                                                   N5251090
       TCH    *-1                                                   N5251100
       TTL    ERROR HANDLING                                        N5251110
NOFILE CALL   .FXEM.(CODEXX)       FILE SEARCH FAILED               N5251120
       RETURN FILE                                                  N5251130
CODEXX DEC    151                                                   N5251140
       IOCD   FAIL,,4                                               N5251150
       IOCD   IGNORF,,3                                             N5251160
       SPACF                                                        N5251170
ERROR  CAL    FCW10,FCB            =FILE NAME                       N5251180
       SLW    NAME                                                  N5251190
       CALL   .FXEM.(CODEYY)       ILLEGAL FILE                     N5251200
       RETURN FILE                                                  N5251210
CODEYY DEC    152                                                   N5251220
       IOCD   BAD,,5                                                N5251230
       IOCD   IGNORE,,3                                             N5251240
       SPACF                                                        N5251250
FAIL   BCI    1,0UNIT                                               N5251260
NUMBER BCI    1,******             UNIT (BCD)                       N5251270
       BCI    2, UNDEFINED                                          N5251280
```

```
BAD    BCI     4,0FILF SKIP ILLEGAL FOR                                 N5251290
NAME   BCI     1,******            FILE NAME                            N5251300
IGNORE BCI     3,0RFQUEST IGNORED.                                      N5251310
       TTL                                                              N5251320
LK.DR  LDIR                                                             N5251330
       END                                                              N5251340
```

3.6 SAMPLE PROBLEM 1

3.6.1 Problem Description and Set-Up

A free cylinder under thermal loading is considered. The geometry and loading is shown in the following figure



$\nu = 0.3$

Normalizing constants

$a_o = 1$
$h_o = 1$
$E_o = 1$
$\sigma_o = 1$

FREE ENDS
No pressure load
Axisymmetric NF = 0
Stiffness Parameters

BBB = 2.4725×10^7 (in plane)
DDD = 1.8887×10^6 (bending)

Thermal Load

ENTT = 9.375×10^4 (in plane)
EMTT = 1.0045×10^4 (bending)

Stress Output Parameters

EI1 = 3×10^7 EI2 = 1.5×10^7

DN1 = -0.4167 DN2 = 0.5833

POIS1 = 0.3 POIS2 = 0.3

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR."

3.6.2 Data Sheets

DECK NO PROGRAMMER DATE 1 2 JOB NO.

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
		Title Cards
CYL		
INDER UNDER		
THERMAL LØAD		
	1	
ARS JØURNAL,		
JANUARY 196		
2		
	2	
RADKØWSKI		
, DAVIS, BØL		
DUC		
	3	
1		GDA, General Data
1.		AO
1.		HO
1.		EO
1.		SIGO
0.3	10	PØI

DECK N — 2 2

NUMBER	IDENTIFICATION	DESCRIPTION	
6			
1.		ENF	
4.		BCIT (free)	
10.		BCIB (special; axisymmetric complete)	
-1.		PFLAG	
	11		
1			GMDA, Geometry Data
1.		GIN (cone-cylinder)	
21.		EN (21 stations)	
10.5		RAI (radius)	
15.	20	A x L (length)	
429			
1.		Ω(3,3)	
	21		
433			
1.		Λ(1,1)	
1.		Λ(2,2)	
1.		Λ(4,4)	
1.	22		

3.6.3 Functional Subprogram Used.

```
$IBFTC BFCN                                                                00000001
C                                                     STIFFNESS FUNCTION   00000009
C                                                                          00000019
      FUNCTION BBB( PFL,ZTA )                                              00000020
C                                                                          00000021
      BBB  =  2.4725274E7                                                  00000100
      RETURN                                                               00000110
C                                                                          00000119
      FNTRY  DDD ( ZTA )                                                   00000120
      BBB  =  1.8887362F6                                                  00000200
      RETURN                                                               00000210
      END                                                                  00000999
```

```
$IBFTC TFCN                                                                00000001
C                                                  TEMPERATURE FUNCTION    00000009
C                                                                          00000019
      FUNCTION  ENTT( PFL,ZTA )                                            00000020
C                                                                          00000021
      ENTT  =  9.375E+4                                                    00000100
      RETURN                                                               00000110
C                                                                          00000119
      ENTRY     EMTT( PFL,ZTA )                                            00000120
      ENTT  =  1.0045F4                                                    00000200
      RETURN                                                               00000210
      END                                                                  00000999
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
$IBFTC [illegible]CN                                                  00000001
C                                                 SPRING FUNCTION     00000009
C                                                                     00000019
      FUNCTION  DKK3( PFL,ZTA )                                       00000020
C                                                                     00000021
      DKK3  =  0.0                                                    00000100
      RETURN                                                          00000110
C                                                                     00000119
      END                                                             00000999
```

```
$IBFTC PFCN                                                           00000001
C                                               PRESSURE FUNCTION     00000009
C                                                                     00000019
      FUNCTION  PPPN( PFL,ZTA )                                       00000020
C                                                                     00000021
      PPPN  =  0.                                                     00000100
      RFTURN                                                          00000110
C                                                                     00000119
      ENTRY     PPPH( PEL,ZTA )                                       00000120
      PPPN  =  0.                                                     00000200
      RETURN                                                          00000210
C                                                                     00000219
      FNTRY     PPPF( PFL,ZTA )                                       00000220
      PPPN  =  0.                                                     00000300
      RFTURN                                                          00000310
      FND                                                             00000999
```

```
$IBFTC STR1FN                                                           00000001
C          1ST SURFACE ** ELASTIC MODULUS, DISTANCE, POISSON'S RATIO    00000009
C                                                                       00000019
      FUNCTION  EI1 ( PEL,ZTA )                                         00000020
C                                                                       00000021
      EI1    =   3.0E+7                                                 00000100
      RETURN                                                            00000110
C                                                                       00000119
      ENTRY      DN1 ( PEL,ZTA )                                        00000120
      EI1    = -0.41666667                                              00000200
      RETURN                                                            00000210
C                                                                       00000219
      ENTRY     POIS1( PEL,ZTA )                                        00000220
      EI1    =   0.3                                                    00000300
      RETURN                                                            00000310
      END                                                               00000999
```

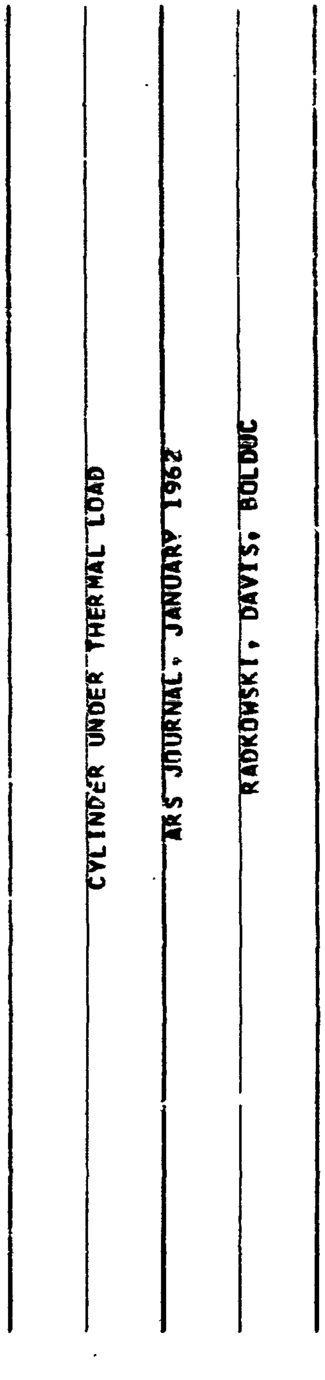
```
$IBFTC STR2FN                                                           00000001
C          2ND SURFACE ** ELASTIC MODULUS, DISTANCE, POISSON'S RATIO    00000009
C                                                                       00000019
      FUNCTION  EI2 ( PEL,ZTA )                                         00000020
C                                                                       00000021
      EI2    =   1.5E+7                                                 00000100
      RETURN                                                            00000110
C                                                                       00000119
      ENTRY      DN2 ( PEL,ZTA )                                        00000120
      EI2    =   0.58333333                                             00000200
      RETURN                                                            00000210
C                                                                       00000219
      ENTRY     POIS2( PEL,ZTA )                                        00000220
      EI2    =   0.3                                                    00000300
      RETURN                                                            00000310
      END                                                               00000999
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
$IBFTC TTF1                                                          00000001
C          1ST SURFACE ** COEF. OF THERMAL EXPANSION, TEMPERATURE    00000009
C                                                                    00000019
      FUNCTION  TMP1( PEL,ZTA )                                      00000020
C                                                                    00000021
      TMP1  =  0.0                                                   00000100
      RETURN                                                         00000110
C                                                                    00000119
      ENTRY      ALF1( PEL,ZTA )                                     00000120
      TMP1  =  10.0E-6                                               00000200
      RETURN                                                         00000210
      END                                                            00000999
```

```
$IBFTC TTF2                                                          00000001
C          2ND SURFACE ** COEF. OF THERMAL EXPANSION, TEMPERATURE    00000009
C                                                                    00000019
      FUNCTION  TMP2( PEL,ZTA )                                      00000020
C                                                                    00000021
      TMP2  =  1000.                                                 00000100
      RETURN                                                         00000110
C                                                                    00000119
      ENTRY      ALF2( PEL,. A )                                     00000120
      TMP2  =  5.0E-6                                                00000200
      RETURN                                                         00000210
      END                                                            00000999
```

3.6.4 Output



```
CYLINDER UNDER THERMAL LOAD
ARS JOURNAL, JANUARY 1962
RADKOWSKI, DAVIS, BOLDUC
```

```
                                   GENERAL DATA

AO     =   1.0000E 00        HO     =   1.0000F 00        FO     =   1.0000F 00        SIGO   =   1.0000E 00
POI    =   3.0000E-01        ENF    =   1.0000E 00        BCIT   =   4.0000E 00        BCIB   =   1.0000E 01
PFLAG =  -1.0000E 00


  PRINT ANGLES (THT) -
                     0.0000E-39  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10
  FOURIER HARMONIC PRINTS (FPRNT) -
                     1.0000E 00  -1.0000E 10  -1.0000E 10  -1.0000E 10


                                 BOUNDARY MATRICES
  TOP BOUNDARY **

  OMEGA
 1.0000000E 00    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 0.0000000E-39    1.0000000E 00    0.0000000F-39    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    1.0000000E 00    0.0000000E-39
 0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    1.0000000E 00

  LAMBDA
 0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
 0.0000000E-39    0.0000000E-39    0.0000000F-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    0.0000000F-39    0.0000000E-39    0.0000000E-39
 0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39

  L -
 0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
```

```
BOTTOM BOUNDARY **

  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    1.0000000E 00    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

  LAMBDA
1.0000000E 00    0.0000000E-39    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    0.0000000E-39    0.0000000E-39    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    1.0000000E 00

  L -
0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
```

```
                         GEOMETRY DATA FOR CONE - CYLINDER

                         NUMBER OF STATIONS -    21

    RAI   =   1.0500E 01       AXL   =   1.5000E 01       ANX   =   0.0000E-39

    DEL   =   7.5000E-01

 I        R(I)             XI(I)          W(THETA)          W(XI)           RHOX(I)          GAMA(I)

 1    1.0500000E 01   0.0000000E-39   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 2    1.0500000E 01   7.5000000E-01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 3    1.0500000E 01   1.5000000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 4    1.0500000E 01   2.2500000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 5    1.0500000E 01   3.0000000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 6    1.0500000E 01   3.7500000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 7    1.0500000E 01   4.5000000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 8    1.0500000E 01   5.2500000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
 9    1.0500000E 01   6.0000000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
10    1.0500000E 01   6.7500000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
11    1.0500000E 01   7.5000000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
12    1.0500000E 01   8.2500000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
13    1.0500000E 01   9.0000000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
14    1.0500000E 01   9.7500000E 00   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
15    1.0500000E 01   1.0500000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
16    1.0500000E 01   1.1250000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
17    1.0500000E 01   1.2000000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
18    1.0500000E 01   1.2750000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
19    1.0500000E 01   1.3500000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
20    1.0500000E 01   1.4250000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
21    1.0500000E 01   1.5000000E 01   9.5238095E-02   0.0000000E-39   1.0500000E 01   0.0000000E-39
```

```
     CHECKPRINT OF COEFC BLOCKS STORED IN GROUPS OF (2*ENF) PER MERIDIONAL STATION.  THE COEFFICIENTS
PRINTED ARE SCB1, SCD1, SCNTSI, SCMTSI, DCK3 (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY THE
THREE ...... FIELDS.


          FOR STATION  1 THROUGH STATION  21

   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
   2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00    2.4725267E 07   -4.7055554E 00
          ......           ......           ......    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06   -2.9236110E-01    1.8887359E 06
  -2.9236110E-01    1.8887359E 06   -2.9236110E-01           ......           ......           ......
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
   9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02    9.3749997E 04   -1.8120659E-02
          ......           ......           ......    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04   -2.0589192E-03    1.0045000E 04
  -2.0589192E-03    1.0045000E 04   -2.0589192E-03           ......           ......           ......
   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   -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
         :                :                :                :                :                :
```

```
CHECKPRINT OF LOAD COEF. STORED IN GROUPS OF ALL ENF PER MERIDIONAL STATION.  THE COEFFICIENTS ARE
PFE, PTH, PN (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY ****** FIELDS.

      FOR STATION  1 THROUGH STATION  21

   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   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   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   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
   0.0000000E-39   0.0000000E-39   0.0000000E-39
```

```
 'Z' MATRIX FOR STATION    21
        0.0000000E-39    0.0000000F-39    3.0273973E-02    2.9521609E-10    0.0000000E-39

 'Z' MATRIX FOR STATION    20
       -2.2108287E-03    0.0000000E-39    3.0281600E-02    2.2427470E-05    0.0000000E-39

 'Z' MATRIX FOR STATION    19
       -4.4213307E-03    0.0000000E-39    3.0304480E-02    5.0239731E-05    0.0000000E-39

 'Z' MATRIX FOR STATION    18
       -6.6311037E-03    0.0000000E-39    3.0349646E-02    9.0617861E-05    0.0000000E-39

 'Z' MATRIX FOR STATION    17
       -8.8395379E-03    0.0000000E-39    3.0429458E-02    1.4980632E-04    0.0000000E-39

 'Z' MATRIX FOR STATION    16
       -1.1045710E-02    0.0000000E-39    3.0560775E-02    2.32[illegible]686E-04    0.0000000E-39

 'Z' MATRIX FOR STATION    15
       -1.3248305E-02    0.0000000E-39    3.0763433E-02    3.3978652E-04    0.0000000E-39

 'Z' MATRIX FOR STATION    14
              :                :                :                :                :
```

```
 'Z' MATRIX FOR STATION      6
      -3.2645028E-02    0.0000000E-39    3.4107951E-02   -1.5989654E-03    0.0000000E-39

 'Z' MATRIX FOR STATION      5
      -3.4790510E-02    0.0000000E-39    3.2547584E-02   -3.3380269E-03    0.0000000E-39

 'Z' MATRIX FOR STATION      4
      -3.6985673E-02    0.0000000E-39    2.9471267E-02   -5.7134319E-03    0.0000000E-39

 'Z' MATRIX FOR STATION      3
      -3.9268604E-02    0.0000000E-39    2.4355890E-02   -8.7390917E-03    0.0000000E-39

 'Z' MATRIX FOR STATION      2
      -4.1688553E-02   -0.0000000E-39    1.6683303E-02   -1.2315728E-02   -0.0000000E-39

 'Z' MATRIX FOR STATION      1
      -4.4304717E-02    0.0000000E-39    6.0422107E-03   -1.6167123E-02   -0.0000000E-39
```

```
STATION    21

THETA  =    0.00

 ENF    =    0.0

              U                V                W               PHI(XI)         PHI(THETA)
        0.0000000E-39    0.0000000E-39    3.0273973E-02    2.9521609E-10    0.0000000E-39


STATION    20

THETA  =    0.00

 ENF    =    0.0

              U                V                W               PHI(XI)         PHI(THETA)
       -2.2108287E-03    0.0000000E-39    3.0281600E-02    2.2427470E-05    0.0000000E-39


STATION    19

THETA  =    0.00

 ENF    =    0.0

              U                V                W               PHI(XI)         PHI(THETA)
       -4.4213307E-03    0.0000000E-39    3.0304480E-02    5.0239731E-05    0.0000000E-39
               .                .                .                .                .
               .                .                .                .                .
```

```
              .            .            .            .            .
              .            .            .            .            .

     THETA  =    0.00

      ENF   =    0.0
                 U             V              W           PHI(XI)      PHI(THETA)
         -3.9268604E-02   0.0000000E-39   2.4355890E-02  -8.7390917E-03  0.0000000E-39


     STATION     2


     THETA  =    0.00

      ENF   =    0.0
                 U             V              W           PHI(XI)      PHI(THETA)
         -4.1688553E-02  -0.0000000E-39   1.6683303E-02  -1.2315728E-02  -0.0000000E-39


     STATION     1


     THETA  =    0.00

      ENF   =    0.0
                 U             V              W           PHI(XI)      PHI(THETA)
         -4.4304717E-02   0.0000000E-39   6.0422107E-03  -1.6167123E-02  -0.0000000E-39
```

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```
   STATION     21

        N(XI)          N(THETA)        N(XI,THETA)        Q(XI)
     5.2645898E 02  -5.9428223E 02   0.0000000E-39   -1.4750057E-03

        M(XI)          M(THETA)        M(XI,THETA)        Q(THETA)
    -1.0094696E 04  -1.0059907E 04   0.0000000E-39   -0.0000000E-39


     STRESSES FOR LAYER    1

       SIG(XI)        SIG(THETA)      SIG(XI,THETA)     SIG(XI,ETA)     SIG(THETA,ETA)
     1.2606342E 05   1.2431609E 05  -0.0000000E-39   -1.9666753E-03   -0.0000000E-39


     STRESSES FOR LAYER    2

       SIG(XI)        SIG(THETA)      SIG(XI,THETA)     SIG(XI,ETA)     SIG(THETA,ETA)
    -4.4544874E 04  -4.5114929E 04   0.0000000E-39   -9.8333765E-04   -0.0000000E-39


   STATION     20

        N(XI)          N(THETA)        N(XI,THETA)        Q(XI)
     5.2107472E 02  -5.7955566E 02   0.0000000E-39    1.8084047E 01

        M(XI)          M(THETA)        M(XI,THETA)        Q(THETA)
    -1.0108257E 04  -1.0063975E 04   0.0000000E-39   -0.0000000E-39


     STRESSES FOR LAYER    1

       SIG(XI)        SIG(THETA)      SIG(XI,THETA)     SIG(XI,ETA)     SIG(THETA,ETA)
     1.2615487E 05   1.2436532E 05  -0.0000000E-39    2.4112076E 01   -0.0000000E-39
          .               .               .                .                .
          .               .               .                .                .
```

```
            .                 .                 .                 .
            .                 .                 .                 .
STATION       2

         N(XI)            N(THETA)         N(XI,THETA)          Q(XI)
     1.0485137E 03    -2.9560514E 04    0.0000000E-39    -9.2257202E 02

         M(XI)            M(THETA)         M(XI,THETA)        Q(THETA)
    -6.9193945E 02    -7.2390801E 03    0.0000000E-39     0.0000000E-39


     STRESSES FOR LAYER    1

         SIG(XI)          SIG(THETA)       SIG(XI,THETA)      SIG(XI,ETA)      SIG(THETA,ETA)
     5.8375792E 04     6.5179318E 04   -0.0000000E-39    -1.2300967E 03     0.0000000E-39

     STRESSES FOR LAYER    2
         SIG(XI)          SIG(THETA)       SIG(XI,THETA)      SIG(XI,ETA)      SIG(THETA,ETA)
     3.6717552E 03    -5.0065183E 04    0.0000000E-39    -6.1504833E 02     0.0000000E-39

STATION       1

         N(XI)            N(THETA)         N(XI,THETA)          Q(XI)
    -7.6171875E-02    -5.2677420E 04    0.0000000E-39     3.6267831E-02

         M(XI)            M(THETA)         M(XI,THETA)        Q(THETA)
    -1.1962891E-02    -7.0315019E 03    0.0000000E-39    -0.0000000E-39


     STRESSES FOR LAYER    1

         SIG(XI)          SIG(THETA)       SIG(XI,THETA)      SIG(XI,ETA)      SIG(THETA,ETA)
     5.1945470E 04     3.7847100E 04   -0.0000000E-39     4.8357133E-02    -0.0000000E-39

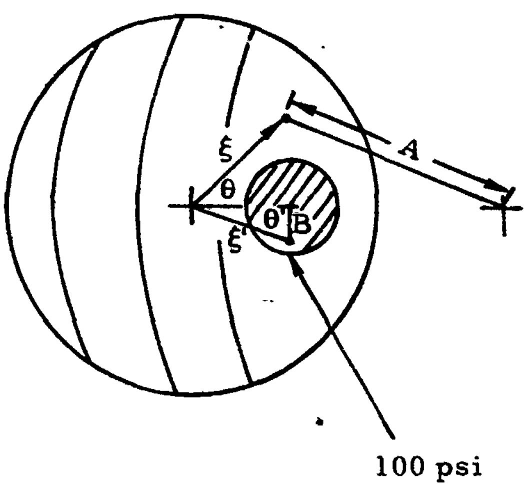
    STRESSES FOR LAYER    2

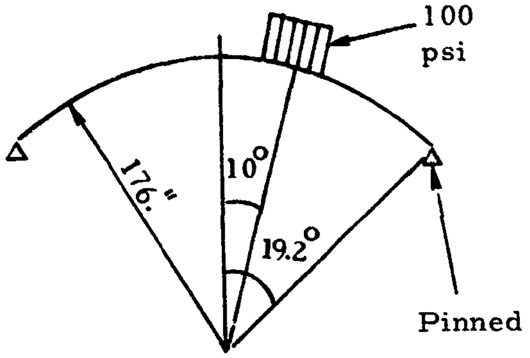
        SIG(XI)          SIG(THETA)       SIG(XI,THETA)      SIG(XI,ETA)      SIG(THETA,ETA)
    6.4952361E 03    -6.4419699E 04    0.0000000E-39     2.4178567E-02    -0.0000000E-39
```

3.7 SAMPLE PROBLEM 2

3.7.1 Problem Description

An Apollo-like shell pinned at the edge is considered.





Normalizing constants

$a_o = 1$
$h_o = 1$
$E_o = 1$
$\sigma_o = 1$

No Thermal Loads

Stiffness Parameter

$A = \xi^2 + 5625 - 2(75)\xi, \cos\theta$

if $A<4425$, $BBB = 3.296 \times 10^6$
$DDD = 3.296 \times 10^6$

if $4425<A<7225$, $BBB = 1.9779 \times 10^6$
$DDD = 1.9779 \times 10^6$

if $7225<A<11025$, $BBB = 1.386 \times 10^6$
$DDD = 1.386 \times 10^6$

if $A>11025$, $BBB = 0.79116 \times 10^6$
$DDD = 0.79116 \times 10^6$

Pressure parameters

Normal pressure definition

$$B = \xi^2 + (30.492)^2 - 2(30.492)\,\xi \cos\theta$$

if $B < 400$ PPPN = 100.0

if $B \geq 400$ PPPN = 0.0

also circumferential and meridional pressures definition

PPPH = PPPF = 0.0

Stress output parameters

EI1 = EI2 = 29.5×10^6 Young's Modulus of stress output location

Distance to neutral surface

$$A = \xi^2 + 5625. - 2(75)\,\xi \cos\theta$$

if $A < 4425$ DN1 = -1.025, DN2 = +1.025

if $4425 < A < 7225$, DN1 = -1.005, DN2 = +1.005

if $7225 < A < 11025$, DN1 = -0.995, DN2 = +0.995

if $A > 11025$, DN1 = -0.987, DN2 = +0.987

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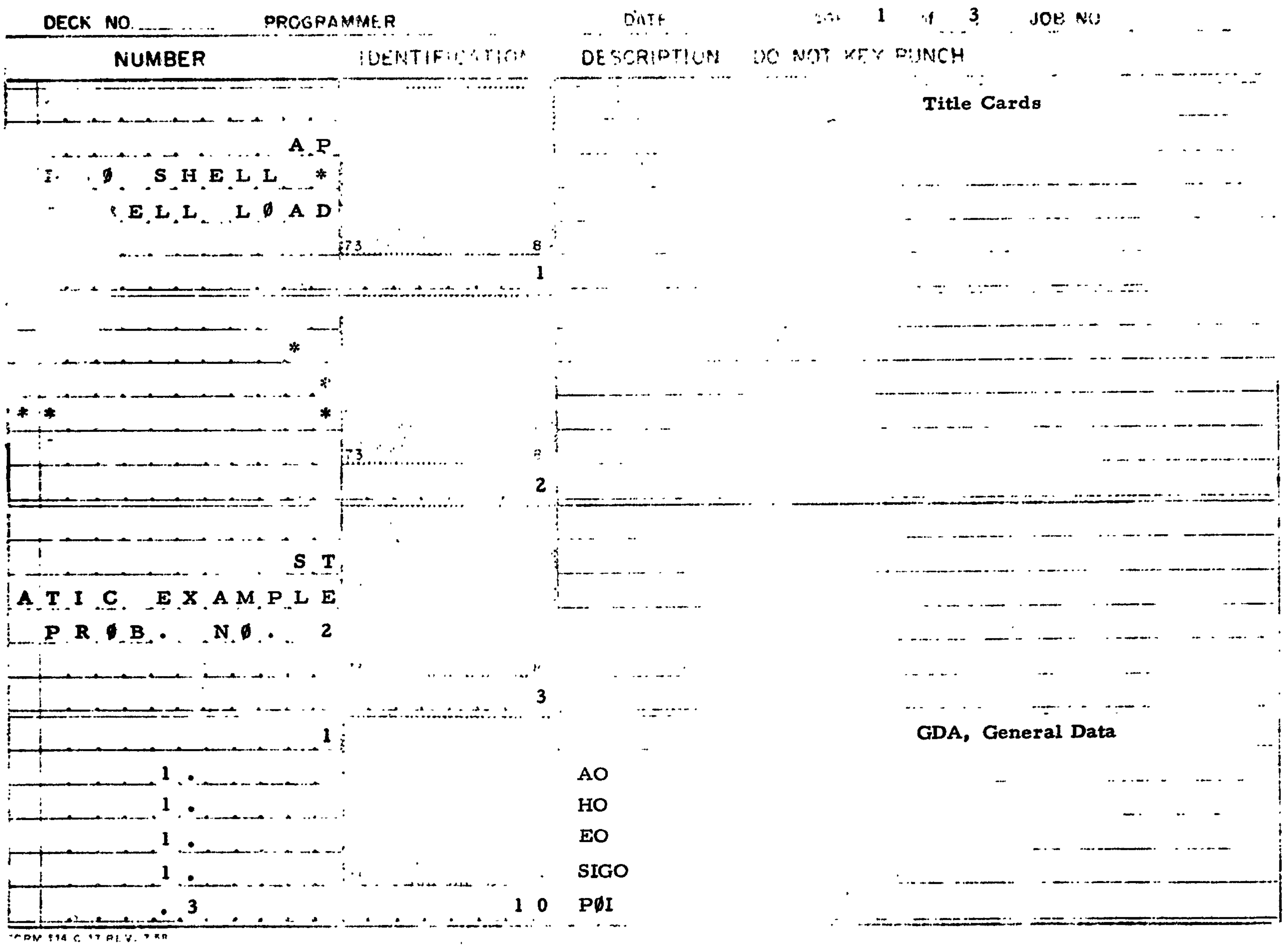
3.7.2 Data Sheets



```
DECK NO.            PROGRAMMER                 DATE            1  of  3   JOB NO
        NUMBER            IDENTIFICATION   DESCRIPTION   DO NOT KEY PUNCH

                                                          Title Cards
                    A P
  I.  Ø  S H E L L   *
       E L L   L Ø A D
                        73               8
                                         1
                    *
                      *
 * *                  *
                        73               8
                                         2

                  S T
A T I C   E X A M P L E
  P R Ø B .   N Ø .   2

                                         3
                      1                                   GDA, General Data
           1 .                               AO
           1 .                               HO
           1 .                               EO
           1 .                               SIGO
         . 3                            1 0  PØI
FORM 114 C 17 REV. 7 58
```

DECK NO. PROGRAMMER DATE PAGE 2 of 3 JOB NO.

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
6		
6.		ENF (No. of Fourier harmonics)
1.		BCIT (Closed apex)
2.		BCIB (Pinned)
-1.		PFLAG
	11	
12		
0.		THT (Thetas to print)
45.		
90.		
135.		
180.	12	
18		
6.		FPRNT (Fourier harmonics to print)
	13	
1		GMDA, Geometry Data
2.		GIN (Sphere)
26.		EN (No. of stations)
176.		RC
	20	RØFF

FORM 114-C-17 REV. 7-58.

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DECK NO. PROGRAMMER DATE PAGE 3 of 3 JOB NO.

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
6		
		PHIO
1 9 . 2		PHIN
	73 80	
	2 1	

FORM 114 C-17 REV. 7 58

3.7.3 Function Subprograms Used

```
$IBFTC BBCN                                                             00000001
                                                  APOLLO SHELL          00000010
C                                                                       00000011
      FUNCTION  BBB (PEL,ZTA)                                           00000015
C                                                                       00000019
      A  =  PEL * PEL + 5625. - 150. * PEL * COS( ZTA )                 00000020
C                                                                       00000029
      IF (A .LE. 4225.)  GO TO 20                                       00000030
      IF (A .LE. 7225.)  GO TO 30                                       00000040
      IF (A .LE. 11025.) GO TO 35                                       00000050
C                                                                       00000059
      K  =  1                                                           00000060
   10 BBB  =  0.79116E6                                                 00000070
      GO  TO  100                                                       00000080
C                                                                       00000089
   20 K  =  2                                                           00000090
   25 BBB  =  3.296E6                                                   00000100
      GO  TO  100                                                       00000110
C                                                                       00000119
   30 K  =  3                                                           00000120
      BBB  =  1.9779E6                                                  00000130
      GO  TO  100                                                       00000140
C                                                                       00000149
   35 K  =  4                                                           00000150
   40 BBB  =  1.386E6                                                   00000160
      GO  TO  100                                                       00000170
C                                                                       00000179
      ENTRY  DDD (ZTA)                                                  00000180
C                                                                       00000189
      IF (K - 2) 10, 25, 50                                             00000190
C                                                                       00000199
   50 IF (K .GT. 3)  GO TO 40                                           00000200
C                                                                       00000209
      BBB  =  1.9779E6                                                  00000210
  100 RETURN                                                            00000999
C                                                                       00001009
      END                                                               00001010
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR."

```
$IBFTC TFCN                                                           00000001
C                                            TEMPERATURE FUNCTION     00000009
C                                                                     00000019
      FUNCTION  ENTT( PFL,7TA )                                       00000020
C                                                                     00000021
      ENTT  =  0.                                                     00000100
      RETURN                                                          00000110
C                                                                     00000119
      ENTRY     EMTT( PEL,ZTA )                                       00000120
      ENTT  =  0.                                                     00000200
      RETURN                                                          00000210
      END                                                             00000999
```

```
$IBFTC KFCN                                                           00000001
C                                                SPRING FUNCTION      00000009
C                                                                     00000019
      FUNCTION  DKK3( PEL,ZTA )                                       00000020
C                                                                     00000021
      DKK3  =  0.0                                                    00000100
      RETURN                                                          00000110
C                                                                     00000119
      END                                                             00000999
```

```
$IBFTC PFCN
C                                                  BELL   LOAD
C
      FUNCTION  PPPN (PFL,ZTA)
C
      A  =  PFL*PFL + 30.492*30.492 - 2.0 * 30.492 * PFL * COS( ZTA )
C
      PPPN  =  0.0
      IF(A .LE. 400.0)  PPPN = 100.0
      RFTURN
C
      ENTRY  PPPH (PFL,ZTA)
      PPPN  =  0.0
      RETURN
C
      ENTRY  PPPF (PEL,ZTA)
      PPPN  =  0.0
      RFTURN
C
      END
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR."

```
$IBFTC STR1FN                                                          00000001
C         1ST SURFACE ** ELASTIC MODULUS, DISTANCE, POISSON'S RATIO    00000009
C                                                  APOLLO  SHELL       00000010
C                                                                      00000019
      FUNCTION  EI1 ( PEL,ZTA )                                        00000020
C                                                                      00000021
      FI1    =  29.5F6                                                 00000100
      RETURN                                                           00000110
C                                                                      00000119
      ENTRY      DN1 ( PEL,ZTA )                                       00000120
C                                                                      00000121
      A  =  PEL * PEL + 5625. - 150. * PEL * COS( ZTA )                00000125
C                                                                      00000129
      IF (A .LE. 4225.)  GO TO 20                                      00000130
      IF (A .LF. 7225.)  GO TO 30                                      00000132
      IF (A .LE. 11025.) GO TO 40                                      00000134
C                                                                      00000139
      EI1   =  -.987                                                   00000140
      GO  TO  100                                                      00000145
C                                                                      00000149
   20 FI1   =  -1.025                                                  00000150
      GO  TO  100                                                      00000155
C                                                                      00000159
   30 EI1   =  -1.005                                                  00000160
      GO  TO  100                                                      00000165
C                                                                      00000169
   40 EI1   =  -.995                                                   00000170
  100 RETURN                                                           00000210
C                                                                      00000219
      ENTRY     POISI( PFL,ZTA )                                       00000220
      EI1   =  0.3                                                     00000300
      RETURN                                                           00000310
      END                                                              00000999
```

```
$IBFTC STR2FN                                                           00000001
C          2ND SURFACE ** ELASTIC MODULUS, DISTANCE, POISSON'S RATIO    00000009
C                                                     APOLLO. SHELL     00000010
C                                                                       00000019
      FUNCTION  EI2 ( PFL,ZTA )                                         00000020
C                                                                       00000021
      EI2   =  29.5E6                                                   00000100
      RETURN                                                            00000110
C                                                                       00000119
      ENTRY     DN2 ( PFL,ZTA )                                         00000120
C                                                                       00000121
      A  =  PEL * PFL + 5625. - 150. * PFL * COS( ZTA )                 00000125
C                                                                       00000129
      IF (A .LE. 4225.)  GO TO 20                                       00000130
      IF (A .LE. 7225.)  GO TO 30                                       00000132
      IF (A .LE. 11025.) GO TO 40                                       00000134
C                                                                       00000139
      EI2  =   .987                                                     00000140
      GO  TO  100                                                       00000145
C                                                                       00000149
   20 EI2  =   1.025                                                    00000150
      GO  TO  100                                                       00000155
C                                                                       00000159
   30 EI2  =   1.005                                                    00000160
      GO  TO  100                                                       00000165
C                                                                       00000169
   40 EI2  =   .995                                                     00000170
  100 RETURN                                                            00000210
C                                                                       00000219
      ENTRY    POIS2( PFL,ZTA )                                         00000220
      EI2   =  0.3                                                      00000300
      RETURN                                                            00000310
      END                                                               00000999
```

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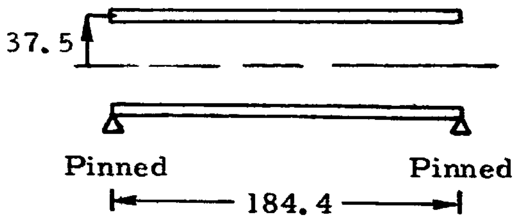
```
$IBFTC TTF1                                                          00000001
C          1ST SURFACE ** COFF. OF THERMAL FXPANSION, TEMPERATURF    00000009
C                                                                    00000019
      FUNCTION  TMP1( PFL,ZTA )                                      00000020
C                                                                    00000021
C                                                                    00000119
      ENTRY     ALF1( PFL.ZTA )                                      00000120
      TMP1  =  0.0                                                   00000200
      RETURN                                                         00000210
      END                                                            00000999
```

```
$IBFTC TTF2                                                          00000001
C          2ND SURFACE ** COEF. OF THERMAL FXPANSION, TEMPERATURF    00000009
C                                                                    00000019
      FUNCTION  TMP2( PFL,ZTA )                                      00000020
C                                                                    00000021
C                                                                    00000119
      FNTRY     ALF2( PFL,ZTA )                                      00000120
      TMP2  =  0.0                                                   00000200
      RFTURN                                                         00000210
      END                                                            00000999
```

3.8 SAMPLE PROBLEM 3

3.8.1 Problem Description

A uniform cylinder under semisinusoidal time dependent loading is considered.



$\nu = 1/6$
$a_o = 1$
$h_o = 1$
$E_o = 1$
$\sigma_o = 1$

Stiffness Parameters

BBB = 12.0925×10^6

DDD = 16.56×10^4

Mass properties DMM1 = 3.49×10^{-3}

No thermal loading

No elastic foundation

No external damping

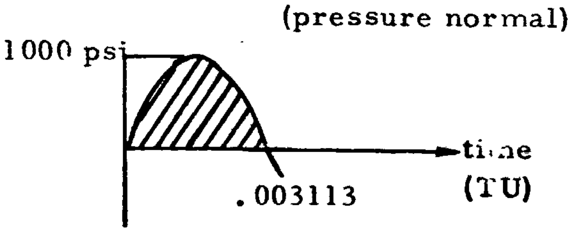
Pressure loading

if TU<.003113

PPPN = 1000 Sin (1003 TU)

if TU ≥.003113

PPPN = 0.0
PPPH = PPPF = 0.0



3.8.2 Data Sheets

DECK NO. ________ PROGRAMMER ________ DATE ________ PAGE 1 of 2 JOB NO. ________

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
		Title Cards
TRANSIENT RE		
SPØNSE ØF A		
SIMPLY SUPPØ		
RTED CYLINDE	73 80	
R	1	
TØ A UNIFØRM		
SINUSØIDAL		
PULSE		
* SHEN	73 80	
G	2	
* *		
*		
	73 80	
	3	
1		GDA, General Data
1.		AO
1.		HO
1.		EO
1.		SIGO
.1667	10	PØI

FORM [illegible] REV. 7-58

DECK NO.______ PROGRAMMER ______ DATE ______ PAGE 2 of 2 JOB NO ______

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
6		
1.		ENF
2.		BCIT
2.		BCIB
- 1.		PFLAG
3.	11	CEXT
- 11		
5. - 4		DELT
	12	
- 1		GMDA, Geometry Data
1.		GIN (cylinder)
11.		EN
37.5		RAI
184.4	20	AXL ANX = 0.

FORM 114-C-17 REV. 7-58

3.8.3. Function Subprograms Used

```
$IBFTC DBBDD                                                               00000001
C                                                     STIFFNESS FUNCTION   00000009
C                                                                          00000019
      FUNCTION BBB( PFL,ZTA )                                              00000020
C                                                                          00000021
      BBB  =  12.0925E+6                                                   00000100
      RETURN                                                               00000110
C                                                                          00000119
      ENTRY  DDD ( ZTA )                                                   00000120
      BBB  =  16.56E+4                                                     00000200
      RETURN                                                               00000210
      END                                                                  00000999
```

```
$IBFTC DTMP                                                                00000001
C                                                   TEMPERATURE FUNCTION   00000009
C                                                                          00000019
      FUNCTION  FNTT( PFL,ZTA )                                            00000020
C                                                                          00000021
C                                                                          00000119
      ENTRY     EMTT( PEL,ZTA )                                            00000120
      ENTT  =  0.                                                          00000200
      RETURN                                                               00000210
      END                                                                  00000999
```

```
$IBFTC DKDMP                                                     00000001
C                                  SPRING AND DAMPING FUNCTION    00000009
C                                                                 00000019
      FUNCTION  DKK1( PEL,ZTA )                                   00000020
C                                                                 00000021
      ENTRY     DKK2( PEL,ZTA )                                   00000120
C                                                                 00000219
      ENTRY     DKK3( PEL,ZTA )                                   00000220
C                                                                 00000319
      ENTRY     DMP1( PEL,ZTA )                                   00000320
C                                                                 00000419
      ENTRY     DMP2( PEL,ZTA )                                   00000420
C                                                                 00000519
      ENTRY     DMP3( PEL,ZTA )                                   00000520
      DKK1  =   0.                                                00000600
      RETURN                                                      00000610
      END                                                         00000999
```

```
$IBFTC DMASS                                                      00000001
C                                          MASS FUNCTION          00000009
C                                                                 00000019
      FUNCTION  DMM1( PEL,ZTA )                                   00000020
C                                                                 00000021
      DMM1 = 3.4900886E-3                                         00000100
      RETURN                                                      00000110
C                                                                 00000119
      ENTRY     DMM4( PEL,ZTA )                                   00000120
      DMM1  =   0.                                                00000200
      RETURN                                                      00000210
      END                                                         00000999
```

```
$IBFTC DPRSS                                                            00000001
C                                                   PRESSURE FUNCTION   00000009
C                                                                       00000019
      FUNCTION  PPPN( PEL,ZTA,TU)                                       00000020
C                                                                       00000021
      IF(TU .LT. 3.113E-3) GO TO 5                                      00000030
      PPPN  =  0.                                                       00000040
      GO  TO  10                                                        00000050
    5 PPPN  =  1000. * SIN(1003. * TU)                                  00000100
   10 RETURN                                                            00000110
C                                                                       00000119
      ENTRY      PPPH( PEL,ZTA,TU )                                     00000120
      PPPN  =  0.                                                       00000200
      RETURN                                                            00000210
C                                                                       00000219
      ENTRY      PPPF( PEL,ZTA,TU )                                     00000220
      PPPN  =  0.                                                       00000300
      RETURN                                                            00000310
      END                                                               00000999
```

3.8.4 Output

```
TRANSIENT RESPONSE OF SIMPLY SUPPORTED CYLINDER TO UNIFORM

SINUSOIDAL PULSE                                  * * *   SHENG

                                * * *
```

```
                                     GENERAL DATA

AO     =   1.0000E 00         HO     =   1.0000E 00         EO     =   1.0000E 00         SIGO   =   1.0000E 00

POI    =   1.6670E-01         ENF    =   1.0000E 00         BCIT   =   2.0000E 00         BCIB   =   2.0000E 00

PFLAG  =  -1.0000E 00         CEXT   =   3.0000E 00         DELT   =   5.0000E-04

   PRINT ANGLES (THT) -

                             0.0000E-39  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10  -1.0000E 10

   FOURIER HARMONIC PRINTS (FPRNT) -

                             1.0000E 00  -1.0000E 10  -1.0000E 10  -1.0000E 10


                                    BOUNDARY MATRICES
   TOP BOUNDARY **

   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
 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    1.0000000E 00

   LAMBDA
 1.0000000E 00    0.0000000E-39    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    1.0000000E 00    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

   L -
 0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
 BOTTOM BOUNDARY **

  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
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    1.0000000E 00


  LAMBDA
1.0000000E 00    0.0000000E-39    0.0000000E-39    0.000      -39    0.0000000E-39
0.0000000E-39    1.0000000E 00    0.0000000E-39    0.00      E-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    0.0000000E-39    0.0000000E-39
0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39

  L -
0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR."

```
                          GEOMETRY DATA FOR CONE - CYLINDER

                         NUMBER OF STATIONS -     11

  RA1   =   3.7500E 01       AXL   =   1.8440E 02       ANX   =   0.0000E-39

  DEL   =   1.8440E 01

I        R(I)             XI(I)           W(THETA)          W(XI)            RHOX(I)          GAMA(I)

1    3.7500000E 01    0.0000000E-39    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
2    3.7500000E 01    1.8440000E 01    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
3    3.7500000E 01    3.6880000E 01    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
4    3.7500000E 01    5.5319999E 01    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
5    3.7500000E 01    7.3759998E 01    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
6    3.7500000E 01    9.2199998E 01    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
7    3.7500000E 01    1.1064000E 02    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
8    3.7500000E 01    1.2908000E 02    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
9    3.7500000E 01    1.4751999E 02    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
10   3.7500000E 01    1.6595999E 02    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
11   3.7500000E 01    1.8439999E 02    2.6666667E-02    0.0000000E-39    3.7500000E 01    0.0000000E-39
```

```
      CHECKPRINT OF COEFF BLOCKS STORED IN GROUPS OF (2*ENF) PER MERIDIONAL STATION.  THE COEFFICIENTS
PRINTED ARE SCB1, SCD1, SCNTSI, SCMTSI, DCM1, DCM4, DCC1, DCC2, DCC3, DCK1, DCK2, DCK3 (IN THAT ORDER)
AND ARE SEPARATED FROM EACH OTHER BY THE THREE ...... FIELDS.


         FOR STATION  1 THROUGH STATION  11

   1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00
   1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00
   1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00
   1.2092497E 07   -2.2277777E 00    1.2092497E 07   -2.2277777E 00           ......           ......
          ......    1.6559999E 05   -2.9296874E-02    1.6559999E 05   -2.9296874E-02    1.6559999E 05
  -2.9296874E-02    1.6559999E 05   -2.9296874E-02    1.6559999E 05   -2.9296874E-02    1.6559999E 05
  -2.9296874E-02    1.6559999E 05   -2.9296874E-02    1.6559999E 05   -2.9296874E-02    1.6559999E 05
  -2.9296874E-02    1.6559999E 05   -2.9296874E-02    1.6559999E 05   -2.9296874E-02           ......
          ......           ......    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   -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    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           ......           ......           ......    3.4900880E-03   -6.1312067E-10
   3.4900880E-03   -6.1312067E-10    3.4900880E-03   -6.1312067E-10    3.4900880E-03   -6.1312067E-10
   3.4900880E-03   -6.1312067E-10    3.4900880E-03   -6.1312067E-10    3.4900880E-03   -6.1312067E-10
   3.4900880E-03   -6.1312067E-10    3.4900880E-03   -6.1312067E-10    3.4900880E-03   -6.1312067E-10
   3.4900880E-03   -6.1312067E-10           ......           ......           ......    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   -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    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   -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    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  -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   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  -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   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  -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   0.0000000E-39
 -0.0000000E-39   0.0000000E-39  -0.0000000E-39
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
CHECKPRINT OF LOAD COEF. STORED IN GROUPS OF ALL ENF PER MERIDIONAL STATION.  THE COEFFICIENTS ARE
PFF, PTH, PN (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY ...... FIELDS.


        FOR STATION  1 THROUGH STATION  11

   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
   0.0000000E-39   0.0000000E-39   0.0000000E-39   0.0000000E-39   0.0000000E-39   0.0000000E-39
   0.0000000E-39          ......          ......          ......   4.8074125E 02   4.8074125E 02
   4.8074125E 02   4.8074125E 02   4.8074125E 02   4.8074125E 02   4.8074125E 02   4.8074125E 02
   4.8074125E 02   4.8074125E 02   4.8074125E 02
```

```
'Z' MATRIX FOR STATION     11
     0.0000000E-39    0.0000000E-39    0.0000000E-39    1.8837273E-04    0.0000000E-39

'Z' MATRIX FOR STATION     10
    -5.4073139E-05   -0.0000000E-39    4.7842581E-03    1.4433218E-04   -0.0000000E-39

'Z' MATRIX FOR STATION      9
    -1.7326856E-05   -0.0000000E-39    5.3232849E-03    1.2210523E-05   -0.0000000E-39

'Z' MATRIX FOR STATION      8
    -2.9512694E-06   -0.0000000E-39    5.2341661E-03   -3.2122134E-06   -0.0000000E-39

'Z' MATRIX FOR STATION      7
    -3.8498865E-07   -0.0000000E-39    5.2047550E-03   -8.4332169E-07   -0.0000000E-39

'Z' MATRIX FOR STATION      6
    -9.0949470E-13   -0.0000000E-39    5.2030697E-03   -1.8189894E-12   -0.0000000E-39

'Z' MATRIX FOR STATION      5
     3.8498592E-07   -0.0000000E-39    5.2047549E-03    8.4332896E-07   -0.0000000E-39
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
'Z' MATRIX FOR STATION      4
        2.9512657E-06   -0.0000000E-39    5.2341662E-03    3.2122225E-06   -0.0000000E-39

'Z' MATRIX FOR STATION      3
        1.7326853E-05   -0.0000000E-39    5.3232850E-03   -1.2210519E-05   -0.0000000E-39

'Z' MATRIX FOR STATION      2
        5.4073140E-05   -0.0000000E-39    4.7842582E-03   -1.4433218E-04   -0.0000000E-39

'Z' MATRIX FOR STATION      1
       -8.5192534E-05   -0.0000000E-39   -6.9652297E-06    1.7655379E-03    0.0000000E-39
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR."

```
     STATION     11

     THETA   =     0.00
      ENF     =    0.0
                  U               V               W             PHI(XI)       PHI(THETA)
           0.0000000E-39   0.0000000E-39   0.0000000E-39   1.8837273E-04   0.0000000E-39


     STATION     10

     THETA   =     0.00
      ENF     =    0.0
                  U               V               W             PHI(XI)       PHI(THETA)
          -5.4073139E-05  -0.0000000E-39   4.7842581E-03   1.4433218E-04  -0.0000000E-39


     STATION      9

     THETA   =     0.00
      ENF     =    0.0
                  U               V               W             PHI(XI)       PHI(THETA)
```

```
     -1.7326856E-05   -0.0000000E-39    5.3232849E-03    1.2210523E-05   -0.0000000E-39


  STATION     8


  THETA   =     0.00

   ENF    =     0.0
          U                V                W             PHI(XI)        PHI(THETA)
     -2.9512694E-06   -0.0000000E-39    5.2341661E-03   -3.2122134E-06   -0.0000000E-39



  STATION     7


  THETA   =     0.00

   ENF    =     0.0
          U                V                W             PHI(XI)        PHI(THETA)
     -3.8498865E-07   -0.0000000E-39    5.2047550E-03   -8.4332169E-07   -0.0000000E-39



  STATION     6


  THETA   =     0.00

   ENF    =     0.0
```

```
             U               V              W             PHI(XI)        PHI(THETA)
      -9.0949470E-13  -0.0000000E-39  5.2030697E-03  -1.8189894E-12  -0.0000000E-39


    STATION      5


    THETA  =     0.00

     ENF    =    0.0
              U               V              W             PHI(XI)        PHI(THETA)
        3.8498592E-07  -0.0000000E-39  5.2047549E-03   8.4332896E-07  -0.0000000E-39


    STATION      4


    THETA  =     0.00

     ENF    =    0.0
              U               V              W             PHI(XI)        PHI(THETA)
        2.9512657E-06  -0.0000000E-39  5.2341662E-03   3.2122225E-06  -0.0000000E-39


    STATION      3


    THETA  =     0.00

     ENF    =    0.0
```

```
         U                V                W             PHI(XI)       PHI(THETA)
  1.7376853E-05   -0.0000000E-39   5.3232850E-03   -1.2210519E-05   -0.0000000E-39


    STATION      2


    THETA  =    0.00
     ENF    =    0.0
         U                V                W             PHI(XI)       PHI(THETA)
  5.4073140E-05   -0.0000000E-39   4.7842582E-03   -1.4433218E-04   -0.0000000E-39


    STATION      1


    THETA  =    0.00
     ENF    =    0.0
         U                V                W             PHI(XI)       PHI(THETA)
 -8.5192534E-05   -0.0000000E-39  -6.9652297E-06    1.7655379E-03    0.0000000E-39
```

```
STATION     11

        N(XI)             N(THETA)          N(XI,THETA)          Q(XI)
     6.5236389E 01     1.0875239E 01     0.0000000E-39     -9.3807093E 02

        M(XI)             M(THETA)          M(XI,THETA)         Q(THETA)
    -8.1676947E-08    -1.3615547E-08     0.0000000E-39     -0.0000000E-39

STATION     10

        N(XI)             N(THETA)          N(XI,THETA)          Q(XI)
     2.6285987E 02     1.5437102E 03     0.0000000E-39     -4.2890719E-02

        M(XI)             M(THETA)          M(XI,THETA)         Q(THETA)
     7.9101019E-01     1.3186140E-01     0.0000000E-39      0.0000000E-39

STATION      9

        N(XI)             N(THETA)          N(XI,THETA)          Q(XI)
     2.6939186E 02     1.7137870E 03     0.0000000E-39      5.6839940E-02

        M(XI)             M(THETA)          M(XI,THETA)         Q(THETA)
     6.6250940E-01     1.1044032E-01     0.0000000E-39      0.0000000E-39

STATION      8

        N(XI)             N(THETA)          N(XI,THETA)          Q(XI)
     2.7580846E 02     1.6869174E 03     0.0000000E-39      8.6695042E-03

        M(XI)             M(THETA)          M(XI,THETA)         Q(THETA)
```

```
        5.8614855E-02    9.7710979E-03    0.0000000E-39    0.0000000E-39


    STATION      7
            N(XI)            N(THETA)        N(XI,THETA)         Q(XI)
        2.7881481E 02    1.6781980E 03    0.0000000E-39   -7.2522718E-04

            M(XI)            M(THETA)        M(XI,THETA)        Q(THETA)
       -1.4423594E-02   -2.4044130E-03    0.0000000E-39    0.0000000E-39


    STATION      6
            N(XI)            N(THETA)        N(XI,THETA)         Q(XI)
        2.7943943E 02    1.6777738E 03    0.0000000E-39    6.7393227E-06

            M(XI)            M(THETA)        M(XI,THETA)        Q(THETA)
       -7.5734623E-03   -1.2624962E-03    0.0000000E-39    0.0000000E-39


    STATION      5
            N(XI)            N(THETA)        N(XI,THETA)         Q(XI)
        2.7881480E 02    1.6781980E 03    0.0000000E-39    7.5393842E-04

            M(XI)            M(THETA)        M(XI,THETA)        Q(THETA)
       -1.4423651E-02   -2.4044226E-03    0.0000000E-39    0.0000000E-39


    STATION      4
            N(XI)            N(THETA)        N(XI,THETA)         Q(XI)
        2.7580848E 02    1.6869174E 03    0.0000000E-39   -8.6554708E-03
```

```
       M(XI)          M(THETA)       M(XI,THETA)      Q(THETA)
   5.8614882E-02   9.7711007E-03   0.0000000E-39   0.0000000E-39

STATION     3
       N(XI)          N(THETA)       N(XI,THETA)        Q(XI)
   2.6935936E 02   1.7136088E 03   0.0000000E-39  -5.6823896E-02

       M(XI)          M(THETA)       M(XI,THETA)      Q(THETA)
   6.6250943E-01   1.1044032E-01   0.0000000E-39   0.0000000E-39

STATION     2
       N(XI)          N(THETA)       N(XI,THETA)        Q(XI)
   2.9079345E 02   1.5483667E 03   0.0000000E-39   9.9445981E-01

       M(XI)          M(THETA)       M(XI,THETA)      Q(THETA)
  -7.9825127E 00  -1.3306849E 00   0.0000000E-39   0.0000000E-39

STATION     1
       N(XI)          N(THETA)       N(XI,THETA)        Q(XI)
   1.4866468E 02   2.2598750E 01   0.0000000E-39   1.0785388E 04

       M(XI)          M(THETA)       M(XI,THETA)      Q(THETA)
  -2.6320569E 01  -4.3876387E 00  -0.0000000E-39   0.0000000E-39
```

```
     CHECKPRINT OF LOAD COEF. STORED IN GROUPS OF ALL ENF PER MERIDIONAL STATION.   THE COEFFICIENTS ARE
PFE, PTH, PN (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY ...... FIELDS.


          FOR STATION  1 THROUGH STATION  11

   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
   0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
   0.0000000E-39           ......           ......           ......    8.4308790E 02    8.4308790E 02
   8.4308790E 02    8.4308790E 02    8.4308790E 02    8.4308790E 02    8.4308790E 02    8.4308790E 02
   8.4308790E 02    8.4308790E 02    8.4308790E 02
```

```
'Z' MATRIX FOR STATION    11
         0.0000000E-39   0.0000000E-39   0.0000000E-39   1.1038860E-03   0.0000000E-39

'Z' MATRIX FOR STATION    10
        -6.3454623E-04   0.0000000E-39   2.5893420E-02   8.6705199E-04   0.0000000E-39

'Z' MATRIX FOR STATION     9
        -3.7170339E-04   0.0000000E-39   3.1978566E-02   1.5654976E-04   0.0000000E-39

'Z' MATRIX FOR STATION     8
        -1.3692552E-04   0.0000000E-39   3.1665081E-02  -2.2956723E-05   0.0000000E-39

'Z' MATRIX FOR STATION     7
        -3.9743107E-05   0.0000000E-39   3.1131263E-02  -1.7755876E-05   0.0000000E-39

'Z' MATRIX FOR STATION     6
        -0.0000000E-39   0.0000000E-39   3.1010200E-02   2.1827873E-11   0.0000000E-39

'Z' MATRIX FOR STATION     5
         3.9743143E-05   0.0000000E-39   3.1131264E-02   1.7755898E-05   0.0000000E-39
```

```
 'Z' MATRIX FOR STATION     4
       1.3692557E-04    0.0000000E-39    3.1665081E-02    2.2956723E-05    0.0000000E-39

 'Z' MATRIX FOR STATION     3
       3.7170340E-04    0.0000000E-39    3.1978566E-02   -1.5654974E-04    0.0000000E-39

 'Z' MATRIX FOR STATION     2
       6.3454624E-04   -0.0000000E-39    2.5893420E-02   -8.6705197E-04   -0.0000000E-39

 'Z' MATRIX FOR STATION     1
      -2.1984192E-11    0.0000000E-39    1.1268639E-09   -1.1038859E-03   -0.0000000E-39
```

```
STATION    11

THETA  =    0.00
 ENF   =    0.0
                  U             V             W            PHI(XI)       PHI(THETA)
        0.0000000E-39  0.0000000E-39  0.0000000E-39  1.1038860E-03  0.0000000E-39

STATION    10

THETA  =    0.00
 ENF   =    0.0
                  U             V             W            PHI(XI)       PHI(THETA)
       -6.3454623E-04  0.0000000E-39  2.5893420E-02  8.6705199E-04  0.0000000E-39

STATION     9

THETA  =    0.00
 ENF   =    0.0
                  U             V             W            PHI(XI)       PHI(THETA)
```

```
     -3.7170339E-04    0.0000000E-39    3.1978566E-02    1.5654976E-04    0.0000000E-39


 STATION      8


 THETA  =    0.00

  ENF   =    0.0
             U                V                W              PHI(XI)          PHI(THETA)
     -1.3692552E-04    0.0000000E-39    3.1665081E-02   -2.2956723E-05    0.0000000E-39


 STATION      7


 THETA  =    0.00

  ENF   =    0.0
             U                V                W              PHI(XI)          PHI(THETA)
     -3.9743107E-05    0.0000000E-39    3.1131263E-02   -1.7755876E-05    0.0000000E-39


 STATION      6


 THETA  =    0.00

  ENF   =    0.0
```

```
                U               V               W               PHI(XI)         PHI(THETA)
   -0.0000000E-39    0.0000000E-39    3.1010200E-02    2.1827873E-11    0.0000000E-39


     STATION     5


     THETA  =     0.00

      ENF    =    0.0
                U               V               W               PHI(XI)         PHI(THETA)
     3.9743143E-05    0.0000000E-39    3.1131264E-02    1.7755898E-05    0.0000000E-39


     STATION     4


     THETA  =     0.00

      ENF    =    0.0
                U               V               W               PHI(XI)         PHI(THETA)
     1.3692557E-04    0.0000000E-39    3.1665081E-02    2.2956723E-05    0.0000000E-39


     STATION     3


     THETA  =     0.00

      ENF    =    0.0
```

```
          U               V               W             PHI(XI)        PHI(THETA)
   3.7170340E-04   0.0000000E-39   3.1978566E-02  -1.5654974E-04   0.0000000E-39


 STATION     2


 THETA  =    0.00

  ENF   =    0.0
          U               V               W             PHI(XI)        PHI(THETA)
   6.3454624E-04  -0.0000000E-39   2.5893420E-02  -8.6705197E-04  -0.0000000E-39


 STATION     1


 THETA  =    0.00

  ENF   =    0.0
          U               V               W             PHI(XI)        PHI(THETA)
  -2.1984192E-11   0.0000000E-39   1.1268639E-09  -1.1038859E-03  -0.0000000E-39
```

```
STATION     11

          N(XI)          N(THETA)         N(XI,THETA)         Q(XI)
      7.1036246E 02   1.1841742E 02    0.0000000E-39    -4.2191703E 03

          M(XI)          M(THETA)         M(XI,THETA)        Q(THETA)
     -5.5540324E-07  -9.2585720E-08    0.0000000E-39    -0.0000000E-39

STATION     10

          N(XI)          N(THETA)         N(XI,THETA)         Q(XI)
      1.5137821E 03   8.3700780E 03    0.0000000E-39    -2.3069341E-01

          M(XI)          M(THETA)         M(XI,THETA)        Q(THETA)
      4.2537650E 00   7.0910262E-01    0.0000000E-39    -0.0000000E-39

STATION      9

          N(XI)          N(THETA)         N(XI,THETA)         Q(XI)
      1.5558496E 03   1.0284818E 04    0.0000000E-39     2.5867319E-01

          M(XI)          M(THETA)         M(XI,THETA)        Q(THETA)
      3.9963506E 00   6.6619164E-01    0.0000000E-39    -0.0000000E-39

STATION      8

          N(XI)          N(THETA)         N(XI,THETA)         Q(XI)
      1.5933162E 03   1.0192784E 04    0.0000000E-39     8.9983445E-02

          M(XI)          M(THETA)         M(XI,THETA)        Q(THETA)
```

```
         7.8267372E-01   1.3047171E-01   0.0000000E-39  -0.0000000E-39


   STATION     7
           N(XI)           N(THETA)        N(XI,THETA)       Q(XI)
         1.6285702E 03   1.0031306E 04   0.0000000E-39   6.1323189E-03

           M(XI)           M(THETA)        M(XI,THETA)      Q(THETA)
        -1.0308124E-01  -1.7183643E-02   0.0000000E-39  -0.0000000E-39


   STATION     6
           N(XI)           N(THETA)        N(XI,THETA)       Q(XI)
         1.6408960E 03   9.9954070E 03   0.0000000E-39   7.6360177E-05

           M(XI)           M(THETA)        M(XI,THETA)      Q(THETA)
        -1.5945630E-01  -2.6581365E-02   0.0000000E-39  -0.0000000E-39


   STATION     5
           N(XI)           N(THETA)        N(XI,THETA)       Q(XI)
         1.6285702E 03   1.0031307E 04   0.0000000E-39  -6.0223427E-03

           M(XI)           M(THETA)        M(XI,THETA)      Q(THETA)
        -1.0308104E-01  -1.7183610E-02   0.0000000E-39  -0.0000000E-39


   STATION     4
           N(XI)           N(THETA)        N(XI,THETA)       Q(XI)
         1.5933164E 03   1.0192785E 04   0.0000000E-39  -8.9919292E-02
```

```
        M(XI)          M(THETA)       M(XI,THETA)        Q(THETA)
    7.8267372E-01   1.3047171E-01   0.0000000E-39   -0.0000000E-39


  STATION      3

        N(XI)          N(THETA)       N(XI,THETA)          Q(XI)
    1.5556607E 03   1.0283748E 04   0.0000000E-39   -2.5856462E-01

        M(XI)          M(THETA)       M(XI,THETA)        Q(THETA)
    3.9963505E 00   6.6619163E-01   0.0000000E-39   -0.0000000E-39


  STATION      2

        N(XI)          N(THETA)       N(XI,THETA)          Q(XI)
    1.5137822E 03   8.3700781E 03   0.0000000E-39    2.3058344E-01

        M(XI)          M(THETA)       M(XI,THETA)        Q(THETA)
    4.2537646E 00   7.0910256E-01   0.0000000E-39    0.0000000E-39


  STATION      1

        N(XI)          N(THETA)       N(XI,THETA)          Q(XI)
    7.1036217E 02   1.184174[illegible] 02   0.0000000E-39    4.2191705E 03

        M(XI)          M(THETA)       M(XI,THETA)        Q(THETA)
   -1.4375143E-06  -2.3963362E-07   0.0000000E-39   -0.0000000E-39
```

```
   CHECKPRINT OF LOAD COEF. STORED IN GROUPS OF ALL ENF PER MERIDIONAL STATION.  THE COEFFICIENTS ARE
PFE, PTH, PN (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY ...... FIELDS.


         FOR STATION  1 THROUGH STATION  11

    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
    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39    0.0000000E-39
    0.0000000E-39           ......           ......           ......    9.9780282E 02    9.9780282E 02
    9.9780282E 02    9.9780282E 02    9.9780282E 02    9.9780282E 02    9.9780282E 02    9.9780282E 02
    9.9780282E 02    9.9780282E 02    9.9780282E 02
```

```
'Z' MATRIX FOR STATION    11
      0.0000000E-39    0.0000000E-39    0.0000000E-39    2.7384748E-03    0.0000000E-39

'Z' MATRIX FOR STATION    10
     -2.1800071E-03    0.0000000E-39    6.0952131E-02    2.1914625E-03    0.0000000E-39

'Z' MATRIX FOR STATION     9
     -1.5983047E-03    0.0000000E-39    8.0825035E-02    5.5042525E-04    0.0000000E-39

'Z' MATRIX FOR STATION     8
     -7.3723757E-04    0.0000000E-39    8.1248075E-02   -4.1839783E-05    0.0000000E-39

'Z' MATRIX FOR STATION     7
     -2.5419031E-04    0.0000000E-39    7.9279975E-02   -7.0573849E-05    0.0000000E-39

'Z' MATRIX FOR STATION     6
     -0.0000000E-39    0.0000000E-39    7.8644956E-02    1.1641532E-10    0.0000000E-39

'Z' MATRIX FOR STATION     5
      2.5419041E-04    0.0000000F-39    7.9279978E-02    7.0573937E-05    0.0000000E-39
```

```
'Z' MATRIX FOR STATION     4
      7.3723778E-04    0.0000000E-39    8.1248075E-02    4.1839696E-05    0.0000000E-39

'Z' MATRIX FOR STATION     3
      1.5983048E-03    0.0000000E-39    8.0825035E-02   -5.5042517E-04    0.0000000E-39

'Z' MATRIX FOR STATION     2
      2.1800072E-03   -0.0000000E-39    6.0952132E-02   -2.1914624E-03   -0.0000000E-39

'Z' MATRIX FOR STATION     1
     -4.9936943E-11    0.0000000E-39    4.3257842E-09   -2.7384744E-03   -0.0000000E-39
```

```
      STATION     11


      THETA  =     0.00

       ENF    =    0.0
                     U                V                W               PHI(XI)         PHI(THETA)
               0.0000000E-39    0.0000000E-39    0.0000000E-39    2.7384748E-03    0.0000000E-39



      STATION     10


      THETA  =     0.00

       ENF    =    0.0
                     U                V                W               PHI(XI)         PHI(THETA)
              -2.1800071E-03    0.0000000E-39    6.0952131E-02    2.1914625E-03    0.0000000E-39



      STATION      9


      THETA  =     0.00

       ENF    =    0.0
                     U                V                W               PHI(XI)         PHI(THETA)
```

```
     -1.5983047E-03    0.0000000E-39    8.0825035E-02    5.5042525E-04    0.0000000E-39


  STATION     8


  THETA  =    0.00

   ENF   =    0.0
         U                V                W             PHI(XI)         PHI(THETA)
     -7.3723757E-04    0.0000000E-39    8.1248075E-02   -4.1839783E-05   0.0000000E-39


  STATION     7


  THETA  =    0.00

   ENF   =    0.0
         U                V                W             PHI(XI)         PHI(THETA)
     -2.5419031E-04    0.0000000E-39    7.9279975E-02   -7.0573849E-05   0.0000000E-39


  STATION     6


  THETA  =    0.00

   ENF   =    0.0
```

```
             U               V               W             PHI(XI)        PHI(THETA)
      -0.0000000E-39  0.0000000E-39  7.8644956E-02  1.1641532E-10  0.0000000E-39


     STATION     5

     THETA  =     0.00
      ENF    =    0.0
             U               V               W             PHI(XI)        PHI(THETA)
       2.5419041E-04  0.0000000E-39  7.9279978E-02  7.0573937E-05  0.0000000E-39


     STATION     4

     THETA  =     0.00
      ENF    =    0.0
             U               V               W             PHI(XI)        PHI(THETA)
       7.3723778E-04  0.0000000E-39  8.1248075E-02  4.1839696E-05  0.0000000E-39


     STATION     3

     THETA  =     0.00
      ENF    =    0.0
```

```
            U                V                W              PHI(XI)        PHI(THETA)
      1.5983048E-03    0.0000000E-39    8.0825035E-02    -5.5042517E-04    0.0000000E-39


   STATION      2


   THETA   =    0.00
    ENF    =    0.0
            U                V                W              PHI(XI)        PHI(THETA)
      2.1800072E-03   -0.0000000E-39    6.0952132E-02    -2.1914624E-03   -0.0000000E-39


   STATION      1


   THETA   =    0.00
    ENF    =    0.0
            U                V                W              PHI(XI)        PHI(THETA)
     -4.9936943E-11    0.0000000E-39    4.3257842E-09    -2.7384744E-03   -0.0000000E-39
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
STATION    11

        N(XI)          N(THETA)        N(XI,THETA)        Q(XI)
   2.3351250E 03   3.8926534E 02    0.0000000E-39   -8.4685251E 03

        M(XI)          M(THETA)        M(XI,THETA)       Q(THETA)
  -1.6335390E-06  -2.7231094E-07    0.0000000E-39   -0.0000000E-39

STATION    10

        N(XI)          N(THETA)        N(XI,THETA)        Q(XI)
   3.8005566E 03   1.9742384E 04    0.0000000E-39   -5.3272472E-01

        M(XI)          M(THETA)        M(XI,THETA)       Q(THETA)
   9.8248624F 00   1.6378045E 00    0.0000000E-39   -0.0000000E-39

STATION     9

        N(XI)          N(THETA)        N(XI,THETA)        Q(XI)
   3.8716973E 03   2.5984509E 04    0.0000000F-39    5.1087612E-01

        M(XI)          M(THETA)        M(XI,THETA)       Q(THETA)
   1.0028058E 01   1.6716772E 00    0.0000000E-39   -0.0000000E-39

STATION     8

        N(XI)          N(THETA)        N(XI,THETA)        Q(XI)
   3.92[illegible]56E 03   2.6126317E 04    0.0000000E-39    2.7448915E-01

        M(XI)          M(THETA)        M(XI,THETA)       Q(THETA)
```

```
        2.7884335E 00     4.6483187E-01     0.0000000E-39     -0.0000000E-39


   STATION      7

          N(XI)              N(THETA)          N(XI,THETA)           Q(XI)
        4.0199776E 03     2.5524842E 04     0.0000000E-39      4.8591152E-02

          M(XI)              M(THETA)          M(XI,THETA)          Q(THETA)
       -1.8787109E-01    -3.1318111E-02     0.0000000E-39     -0.0000000E-39


   STATION      6

          N(XI)              N(THETA)          N(XI,THETA)           Q(XI)
        4.0608813E 03     2.5332579E 04     0.0000000E-39      2.0484360E-04

          M(XI)              M(THETA)          M(XI,THETA)          Q(THETA)
       -6.3378710E-01    -1.0565231E-01     0.0000000E-39     -0.0000000E-39


   STATION      5

          N(XI)              N(THETA)          N(XI,THETA)           Q(XI)
        4.0199776E 03     2.5524843E 04     0.0000000E-39     -4.8151247E-02

          M(XI)              M(THETA)          M(XI,THETA)          Q(THETA)
       -1.8786965E-01    -3.1317871E-02     0.0000000E-39     -0.0000000E-39


   STATION      4

          N(XI)              N(THETA)          N(XI,THETA)           Q(XI)
        3.9267862E 03     2.6126318E 04     0.0000000E-39     -2.7442041E-01
```

```
             M(XI)          M(THETA)       M(XI,THETA)     Q(THETA)
          2.7884336E 00   4.6483188E-01   0.0000000E-39   -0.0000000E-39

    STATION     3

             N(XI)          N(THETA)       N(XI,THETA)      Q(XI)
          3.8712259E 03   2.5981806E 04   0.0000000E-39   -5.1056799E-01

             M(XI)          M(THETA)       M(XI,THETA)     Q(THETA)
          1.0028057E 01   1.6716771E 00   0.0000000E-39   -0.0000000E-39

    STATION     2

             N(XI)          N(THETA)       N(XI,THETA)      Q(XI)
          3.8005567E 03   1.9742384E 04   0.0000000E-39    5.3257809E-01

             M(XI)          M(THETA)       M(XI,THETA)     Q(THETA)
          9.8248610E 00   1.6378043E 00   0.0000000E-39    0.0000000E-39

    STATION     1

             N(XI)          N(THETA)       N(XI,THETA)      Q(XI)
          2.3351237E 03   3.8926515E 02   0.0000000E-39    8.4685262E 03

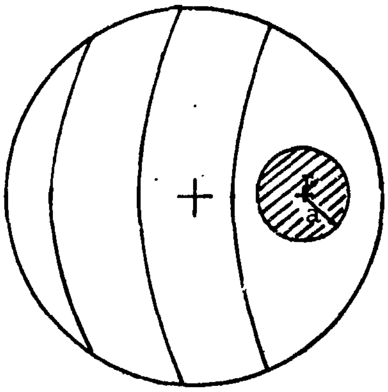
             M(XI)          M(THETA)       M(XI,THETA)     Q(THETA)
         -4.7045922E-06  -7.8425551E-07   0.0000000E-39   -0.0000000E-39

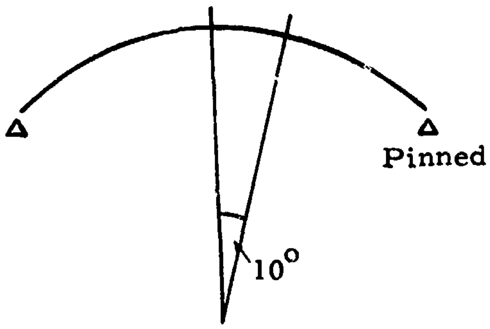

END EXECUTION     32                                        00-09-20
D06961FURUIKE       8302517-11  980              00-09-22    03/03/77
JOB TOTALS=     **PRINTING=   228 LINES **PUNCHING=       7 CARDS    **CRT=     00000-35MM  00000-9INCH
```

3.9 SAMPLE PROBLEM 4

3.9.1 Problem Description

The Apollo-like shell of sample problem 1, Section 3.7 is now subjected to hydrodynamic pressures compacted from a rigid shell solution.





All the input parameters are the same as sample problem 1 except for the subroutine describing pressures.

V_o	= 360 in./s	Initial impact velocity
R_c	= 175.6 in.	Radius of curvature
ρ_w	= 62.5/17280 #/in.^{3}	Fluid density
W_T	= 10,000	Weight of body

inside wetted region

$$PPPN = \frac{\sqrt{2}\,\rho_w V_o^{3/2} R_c^{1/2} \left|1 - \gamma(2 - 3r^2/a^2)\right|}{\pi t^{1/2}(1 - r^2/a^2)^{1/2}(1 + \gamma)^2}$$

where

$$t = \frac{1}{R_c V_o}\left(\frac{3W_T}{4\sqrt{2}\,\rho_w}\right)^{2/3}, \qquad \gamma = \frac{8\sqrt{2}\,\rho_w\left(R_c V_o t\right)^{3/2}}{3W_T}$$

outside wetted region

$$PPPN = 0.0$$

also

$$PPPH = PPPF = 0.0$$

The mass properties of the Apollo-like shell.

$$DMM1 = 1.4648 \times 10^{-3}(t_f) + 4.7443 \times 10^{-5}$$

where

$$A = \xi^2 + 5625 - 2(75)\xi \cos\theta$$

$A < 4225$ $\quad t_f = 0.05$

$4225 < A < 7225$ $\quad t_f = 0.03$

$7225 < A < 11025$ $\quad t_f = 0.02$

$A > 11025$ $\quad t_f = 0.012$

3.9.2 Data Sheets

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 1 2 JOB NO. ______

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
APØLLØ SHELL		Title Cards
* UNSYMMETR		
IC RIGID BØD		
Y HYDRØDYNAM		
ICS PRESSURE		
*	1	
TEN DEGRE		
E ØFFSET CAS		
E		
	2	
REFEREN		
CE * FØURTH		
QUARTERLY RE		
PØRT		
	3	
1		GDA, General Data
1		A0
1		H0
1		E0
1		SIG0
3	10	PØI

FORM 114-C-17 REV. 7-58

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 2 of 2 JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
	6		GDA, continued
	1.		ENF (No. of Fourier harmonics)
	1.		BCIT (Closed apex)
	2.		BCIB (Pinned)
	-1.		PFLAG
	6.	11	CEXT (No. of time cycles)
-	11		
	5. -4		DELT (Time increment)
		12	THT & FPRNT are set by the program.
	1		GMDA, Geometry Data
	2.		GIN (Sphere)
	26.		EN (No. of stations)
	176.		RC
		20	RØFF
-	7		
	19.2		PHIN
			(PHIO = 0.0)
		21	

FORM 114-C-17 REV. 7-58

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3.9.3 Function Subprogram Used

```
$IBFTC DBGOD                                                            00000001
C                                                      APOLLO  SHELL    00000010
C                                                                       00000011
      FUNCTION  BBB (PFL,ZTA)                                           00000015
C                                                                       00000019
      A  =  PFL * PFL + 5625. - 150. * PFL * COS( ZTA )                 00000020
C                                                                       00000029
      IF (A .LE. 4225.)  GO TO 20                                       00000030
      IF (A .LE. 7225.)  GO TO 30                                       00000040
      IF (A .LE. 11025.) GO TO 35                                       00000050
C                                                                       00000059
      K  =  1                                                           00000060
   10 BBB  =  0.79116E6                                                 00000070
      GO  TO  100                                                       00000080
C                                                                       00000089
   20 K  =  2                                                           00000090
   25 BBB  =  3.296E6                                                   00000100
      GO  TO  100                                                       00000110
C                                                                       00000119
   30 K  =  3                                                           00000120
      BBB  =  1.9779E6                                                  00000130
      GO  TO  100                                                       00000140
C                                                                       00000149
   35 K  =                                                              00000150
   40 BBB  =  1.386E6                                                   00000160
      GO  TO  100                                                       00000170
C                                                                       00000179
      ENTRY  DDD (ZTA)                                                  00000180
C                                                                       00000189
      IF (K - 2) 10, 25, 50                                             00000190
C                                                                       00000199
   50 IF (K .GT. 3)  GO TO 40                                           00000200
C                                                                       00000209
      BBB  =  1.9779E6                                                  00000210
  100 RETURN                                                            00000999
C                                                                       00001009
      END                                                               00001010
```

```
$IBFTC DTMP                                                   00000001
C                                       TEMPERATURE FUNCTION  00000009
C                                                             00000019
      FUNCTION  ENTT( PEL,ZTA )                               00000020
C                                                             00000021
C                                                             00000119
      ENTRY      EMTT( PEL,ZTA )                              00000120
      ENTT  =  0.                                             00000200
      RETURN                                                  00000210
      END                                                     00000999
```

```
$IBFTC DKDMP                                                  00000001
C                                  SPRING AND DAMPING FUNCTION 00000009
C                                                             00000019
      FUNCTION  DKK1( PEL,ZTA )                               00000020
C                                                             00000021
      ENTRY     DKK2( PEL,ZTA )                               00000120
C                                                             00000219
      ENTRY     DKK3( PEL,ZTA )                               00000220
C                                                             00000319
      ENTRY     DMP1( PEL,ZTA )                               00000320
C                                                             00000419
      ENTRY     DM[illegible] PEL,ZTA )                       00000420
C                                                             00000519
      ENTRY     DMP3( PEL,ZTA )                               00000520
      DKK1  =  0.                                             00000600
      RETURN                                                  00000610
      END                                                     00000999
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
$IBFTC DMASS                                                       00000001
C                                                   MASS FUNCTION  00000009
C                                                 APOLLO  SHELL    00000010
C                                                                  00000019
      FUNCTION  DMM1( PEL,ZTA )                                    00000020
C                                                                  00000021
      A  =  PEL * PEL + 5625. - 150. * PEL * COS( ZTA )            00000125
C                                                                  00000129
      IF (A .LE. 4225.)  GO TO 20                                  00000130
      IF (A .LE. 7225.)  GO TO 30                                  00000132
      IF (A .LE. 11025.) GO TO 40                                  00000134
C                                                                  00000139
      TF  =  .012                                                  00000140
      GO  TO  100                                                  00000145
C                                                                  00000149
   20 TF  =  .05                                                   00000150
      GO  TO  100                                                  00000155
C                                                                  00000159
   30 TF  =  .03                                                   00000160
      GO  TO  100                                                  00000165
                                                                   00000169
   40 TF  =  .02                                                   00000170
  100 DMM1  =  1.4648033E-3 * TF + 4.7443145E-5                    00000180
      RETURN                                                       00000210
C                                                                  00000219
      ENTRY     DMM4( PEL,ZTA )                                    00000220
      DMM1  =  0.                                                  00000300
      RETURN                                                       00000310
      END                                                          00000999
```

```
$IBFTC DPRSS                                                            00000005
C            PRESSURE FUNCTION  **  RIGID BODY HYDRODYNAMICS PRESSURE ** 00000010
C                                                                       00000014
      FUNCTION PPPN (PFL.ZTA,TU)                                        00000015
C                                                                       00000016
      COMMON    GDA(25), DEL                                            00000020
C                                                                       00000021
C                  UNSYMMETRIC PRESSURE CASE * 10 DEGREE OFFSET *       00000022
C                  CONSTANTS SET TO APOLLO IMPACT CASE                  00000023
C                                                                       00000024
C     VIN     INITIAL IMPACT VELOCITY, IN /SEC                          00000029
      VIN  =  360.0                                                     00000030
C     R       RADIUS OF CURVATURE                                       00000034
      R  =  175.6                                                       00000035
C     RHO     FLUID DENSITY, LBS /CU IN                                 00000039
      RHO  =  62.5 /1728.0                                              00000040
C     WT      WEIGHT OF BODY, LBS                                       00000044
      WT  =  10000.0                                                    00000045
C                                                                       00000099
      RMAX  =  SQRT (2.0 * TU * R * VIN)                                00000100
      A3  =  1.3333 * RHO * RMAX **3 /WT                                00000110
      BAF  =  A3 + 1.0                                                  00000120
      A1  =  2.0 * R * VIN **2 * RHO /(3.1415927 * RMAX * 386.4 *BAF**2)00000130
      A  =  2.0 * RHO * RMAX **3 /WT                                    00000140
      B  =  A1 * RMAX * (1.0 - 4.0 * A /3.0)                            00000150
      SII  =  RMAX - DEL                                                00000160
      SI  =  SQRT (DEL **2 + 929.762 - 60.984 * PFL * COS(ZTA))         00000170
      ROC  =  SI /RMAX                                                  00000180
C                                                                       00000189
      IF(SI .GT. RMAX) GO TO 40                                         00000190
C                                                                       00000199
      IF(SI .LT. RMAX .AND. SI .GT. SII) GO TO 30                       00000200
C                                                                       00000209
   20 PPPN  =  -A1 *(1.0 - A3 *(2.0 - 3.0 * ROC **2)) /SQRT(1.0 -ROC**2)00000210
      GO  TO  50                                                        00000220
C                                                                       00000227
C                          WETTED BOUNDARY, PRESSURE AVERAGED OVER DEL  00000228
C                                                                       00000229
   30 RORM  =  SII /RMAX                                                00000230
      PPPN  =  -B *((1.0 + A) * 3.1415927 /2.0 - ((1.0 + A) * ARSIN     00000240
     1 (RORM) - A * RORM * SQRT(1.0 - RORM **2))) /DEL                  00000241
      GO  TO  50                                                        00000250
C                                                                       00000259
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR;

```
   40 PPPN   =  0.0                                               00000260
C                                                                 00000269
   50 RETURN                                                      00000270
C                                                                 00000279
      ENTRY    PPPH (PFL,ZTA,TU)                                  00000280
      PPPN   =  0.0                                               00000290
      RETURN                                                      00000300
C                                                                 00000309
      ENTRY    PPPF (PFL,ZTA,TU)                                  00000310
      PPPN   =  0.0                                               00000320
      RETURN                                                      00000330
      END                                                         00000500
```

3.10 ERROR INDICATIONS, PITFALLS, RECOMMENDATIONS

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

1. A bad index on a DECRD card (Section 3.5.1)
2. Omission of the negative sign on the last card of a data array (Section 3.5.1)
3. Omission of some or all of the title cards (Section 3.3.1).

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 digital computer.

The amount of data entered by the DECRD routine is relatively small but such things as sign convention, angle measurements, and compatibility of units are common pitfalls.

Many of the needed parameters are supplied to the program by use of FUNCTION subprograms. Before writing such subprograms, Section 3.4, 3.6.3, 3.7.3, 3.8.3 and 3.9.3 should be studied. A check list is given below.

1. Are the FUNCTION and ENTRY names spelled the same as those given in the table of Section 3.4?
2. Does the number of arguments agree with the number in the calling program? Note that ENTRY DDD has just one argument, (ZTA), and the pressure functions for the Dynamics version require the added argument TU.
3. Has the FUNCTION name been used to return the function value to the calling program even when reference was made to an ENTRY name?
4. Does the FUNCTION subprogram contain at least one RETURN statement and an END statement?
5. If additional data were needed to define the function have the data cards been included with the data deck?

3.11 PROGRAM LISTINGS FOR STATIC VERSION

3.11a Main Program

```
$IBFTC MAIN                                                             00000010
C        APOLLO WATER IMPACT ANALYSIS                **            **   00000020
C                                                                       00000030
C  REFERENCES ** AIAA JOURNAL, VOL. 1, NO. 8, AUG. 1963, PG.1833FF AND  00000040
C                VOL. 2, NO. 3, MARCH 1964, PG. 590FF                   00000050
C              ** SID 65-1633 REPORT, APOLLO WATER IMPACT ANALYSIS, NOV. 00000060
C                 23, 1965, PG. 81FF                                    00000070
C                                                                       00000080
C     NOMENCLATURE                                                      00000090
C           AO        REFERENCE LENGTH (IN)                             00000100
C           HO        REFERENCE THICKNESS (IN)                          00000110
C           EO        REFFRENCE YOUNG MODULUS (PSI)                     00000120
C           SIGO      REFERENCE STRESS (PSI)                            00000130
C           POI       POISSON RATIO                                     00000140
C           ENF       NO. OF FOURIER COMPONENTS                         00000150
C           BCIT      TOP BOUNDARY CONDITION FLAG                       00000180
C           BCIB      BOTTOM BOUNDARY CONDITION FLAG.                   00000181
C                 = 1.0     CLOSED APEX                                 00000182
C                 = 2.0     PINNED                                      00000183
C                 = 3.0     CLAMPED                                     00000184
C                 = 4.0     FREE                                        00000185
C                 = 5.0     ROLLER W                                    00000186
C                 = 6.0   ' ROLLER U                                    00000187
C                 = 10.0    SPECIAL BOUNDARY READ WITH GEOMETRY DATA    00000195
C           PFLAG     DATA PRINT INDICATOR                              00000220
C                 = 0.0     PRINTS GENERAL DATA AND BND. MATRICES       00000221
C                 = 1.0     PRINTS ABOVE INFORMATION AND INPUT DATA     00000222
C                           FOR A PARTICULAR GEOMETRY, AND THE PARA-    00000223
C                           METERS COMPUTED IN  GEOM                    00000224
C                 =-1.0     PRINTS ALL OF THE ABOVE INFORMATION AND     00000225
C                           STIFFNESS COEFFICIENTS, ELASTIC COFF.,      00000226
C                           THERMAL LOAD AND MOMENT AND PRESSURES       00000227
C           THT       CIRCUMFERENTIAL ANGLE THETA (DEGREES)  5 MAX      00000230
C           FPRNT     FOURIER COMPONENT PRINT VALUES. 3 PERMITTED       00000231
C                                                                       00000239
C     TAPE USAGE -                                                      00000240
C           TAPE  3 -      THREE FILES.                                 00000250
C                          FIRST FILE  - FOURIER COEFFICIENTS FOR LOAD. 00000260
C                          SECOND FILE - INITIAL BOUNDARY MATRICES      00000270
C                                        GENERATED IN 'RSLT'.           00000271
C                          THIRD FILE  - MATRICES FROM STATION NO. 1.   00000290
C                                                                       00000299
C           TAPE  4        TWO FILES.                                   00000300
```

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```
C                         FIRST FILE  - A RECORD OF EACH REGION STUDIED 00000310
C                                       IN 'GEOMETRY'.                  00000311
C                                       A LAST RECORD CONTAINING A 'P'  00000330
C                                       AND AN 'X' GENERATED FOR        00000331
C                                       STATION (N-2).  THIS RECORD IS  00000332
C                                       WRITTEN IN FGMTX AND BACKSPACED.00000333
C                         SECOND FILE - A 'Z' MATRIX FOR EACH STATION.  00000360
C                                                                       00000369
C           TAPE  9 -     ONE FILE.                                     00000370
C                                       STIFFNESS COEFFICIENTS GENERATED00000380
C                                       IN 'DATLYR'.                    00000390
C                                                                       00000399
C           TAPE 10 -     ONE FILE.                                     00000400
C                                       EACH RECORD CONTAINS 'P' AND 'X'00000410
C                                       FOR EACH STATION.  LAST RECORD  00000411
C                                       CONTAINS ONLY R, S, AA0, AND    00000412
C                                       L1 FOR LAST STATION.            00000413
C                                                                       00000420
      DIMENSION   BCD(36), THT(6), FPRNT(3)                             00000430
C                                                                       00000450
      EQUIVALENCE (GDA( 1),   A0),                 (GDA( 2),   H0),     00000460
     1            (GDA( 3),   E0),                 (GDA( 4), SIG0),     00000470
     2            (GDA( 5),  POI),                 (GDA( 6),  ENF),     00000480
     3            (GDA( 7), BCIT),                 (GDA( 8), BCIB),     00000481
     4            (GDA( 9),PFLAG),                                      00000482
     5                                             (GDA(12),  THT),     00000483
     6            (GDA(18),FPRNT)                                       00000484
C                                                                       00000500
      COMMON  GDA(25), DEL, N, NNF, NTH,                                00000510
     1 BMTX(160)                                                        00000520
C                                                                       00000530
    5 REWIND  3                                                         00000540
      REWIND  10                                                        00000545
      REWIND  4                                                         00000550
      REWIND  9                                                         00000560
C                                 READ AND PRINT 3 CARDS OF TITLE DATA  00000561
      READ (5,7)  BCD                                                   00000562
    7 FORMAT( 12A6 )                                                    00000563
      WRITE (6,8) BCD                                                   00000564
    8 FORMAT(1H1 /(18X, 12A6 //) )                                      00000565
C                                                                       00000569
      DO 10 L = 1,11                                                    00000570
      GDA(L+11)  =  -1.E+10                                             00000575
```

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```
   10 GDA(L) = 0.0                                                      00000580
C                                                                       00000590
C                                   READ GENERAL DATA                   00000599
   20 CALL DECRD (GDA)                                                  00000600
      IF(THT(1) .EQ. -1.E+10)  THT(1)  =  0.0                           00000602
      IF(FPRNT(1) .EQ. -1.E+10)  FPRNT(1)  =  ENF                       00000603
C                                                                       00000610
C                                               DATA  LINK              00000619
      CALL DATLNK                                                       00000620
C                                                                       00000680
C                                    FORM 'P' AND 'X' MATRICES          00000689
      CALL PANDX                                                        00000690
      REWIND  9                                                         00000700
C                                                                       00000710
C                                               SOLUTIONS               00000719
      CALL ZMTRX                                                        00000720
C                                                                       00000730
C                                   SUMS AND INTERNAL LOADS             00000739
      CALL SUMS                                                         00000740
C                                                                       00000750
      GO  TO  5                                                         00000760
C                                                                       00009999
      END                                                               00010000
```

3.11b DATLNK Subroutine (DLNK)

```
$IBFTC DLNK                                                                      00000001
C        SUB-EXECUTIVE ROUTINE FOR GEOM, DATLYR AND DATLD TO PERMIT ONE          00000010
C           COPY OF CUDIMA, ENTERP AND DINTRP IN THE DECK SET-UP                 00000011
C                                                                                00000019
         SUBROUTINE DATLNK                                                       00000020
C                                                                                00000099
         COMMON    GDA(25), DEL, N, NNF, NTH, BMTX(160)                          00000100
C                                                                                00000198
C                                         SET UP R, RHOX, GAMA, WTH, WFL, XSI    00000199
         CALL  GEOM                                                              00000200
         BACKSPACE  4                                                            00000205
C                                                                                00000218
C                                               SET UP MATERIAL PROPERTIES       00000219
         CALL  DATLYR                                                            00000220
         REWIND  9                                                               00000225
C                                                                                00000238
C                                               SET UP FOURIER LOAD COEFF.       00000239
         CALL  DATLD                                                             00000240
C                                                                                00000999
         RETURN                                                                  00001000
C                                                                                00001009
         END                                                                     00001010
```

3.11c GEOM Subroutine (GMTRY)

```
$IBFTC GMTRY                                                            00000010
C     * *  APOLLO WATER IMPACT STUDY    * *     GEOMETRY COMPUTATION ** 00000020
C                                                                       00000030
      SUBROUTINE GEOM                                                   00000040
C                                                                       00000050
C         GMI    -  GEOMETRY INDICATOR                  VIZ.     GIN    00000060
C                =  1.0  - CONE - CYLINDER                        **    00000070
C                =  2.0  - SPHERE - TOROID                        **    00000080
C                =  3.0  - ARBITRARY FUNCTIONS                    **    00000090
C                =  4.0  - GENERAL DISCRETE POINTS                **    00000100
C                 **                                              **    00000110
C        INPUTS -     GMI = 1.0                                         00000120
C                  RA1    =   RADIUS AT STATION 1                       00000130
C                  AXL    =   AXIAL SURFACE LENGTH                      00000140
C                  ANX    =   ANGLE - GENERATOR AND AXIS OF REVOLUTION  00000150
C                 **                                              **    00000160
C                     GMI = 2.0                                         00000170
C               RC    =  RADIUS OF CURVATURE                            00000180
C               ROFF  =  OFFSET DISTANCE TO CENTER OF CURVATURE         00000190
C               PHI0  = INITIAL  OPENING ANGLE FROM VERTICAL AXIS       00000200
C               PHIN  =  FINAL ANGLE                                    00000210
C                 **                                              **    00000220
C                   GMI  = 4.0  (- 4.0 DISCRETE ARCLENGTHS )            00000230
C               EM    =  NUMBER OF RIPTS GIVEN                          00000240
C               RIPT  =  DISCRETE RADII                                 00000250
C               XIPT  =  DISCRETE XI'S (OR ARCLENGTHS)                  00000260
C               RCURV =  MERIDIONAL RADII OF CURVATURE                  00000270
C               RCURZ =  CIRCUMFERENTIAL RADII OF CURVATURE             00000280
C                 **                                              **    00000290
C                                                                       00000300
      DIMENSION WFW(16), WFP(4), STAP(4), STAW(16) , RRJ(12), RCRV(100),00000310
     1RCURZ(100), RCURV(100), RR(100), RIPT(100),XIPT(100), SARB(100),  00000320
     2SURF(100), XJ(11), RJ(11), DLR(100), R(100), XSI(100), WTHX(100), 00000330
     3WFEX(100), RHOX(100), GAMA(100), WFFPX(100), RCRZ(100), GMDA(442) 00000340
C                                                                       00000350
      DIMENSION BNDTX(17), BNDTB(17), THT(6), FPRNT(4)                  00000360
      DIMENSION  OMG0(5,5),  OMGN(5,5), ALMU(5,5), ALMN(5,5)            00000370
      DIMENSION  ALMI(5,5), OMGI(5,5)                                   00000380
      REAL  LLO(5),  LLLN(5)                                            00000390
C                                                                       00000400
      COMMON  GDA(29), DEL, N, NNF, NTH,                                00000410
     1 AMTX(160)                                                        00000420
C                                                                       00000430
```

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```
      EQUIVALENCE  (BMTX(  1), OMG0),          (BMTX( 26), OMGN),        00000440
     1             (BMTX( 51), ALM0),          (BMTX( 76), ALMN),        00000450
     2             (BMTX(101), OMG1),          (BMTX(126), ALM1),        00000460
     3             (BMTX(151),  LL0),          (BMTX(156), LLLN)         00000470
C                                                                        00000479
      EQUIVALENCE (GDA( 1),   A0),          (GDA( 2),   H0),             00000480
     1            (GDA( 3),   E0),          (GDA( 4), SIG0),             00000490
     2            (GDA( 5),  POI),          (GDA( 6),  ENF),             00000500
     3            (GDA( 7), BCIT),          (GDA( 8), BCIB),             00000510
     4            (GDA( 9),PFLAG),                                       00000511
     5                                      (GDA(12),  THT),             00000512
     6            (GDA(18),FPRN)                                         00000513
C                                                                        00000520
      EQUIVALENCE  (GMDA(  1),        GIN), (GMDA(  2),        FN),      00000530
     1             (GMDA(  3),      BLANK), (GMDA(  4),    RA1,RC),      00000540
     2             (GMDA(  5),   AXL,ROFF), (GMDA(  6),  ANX,PHI0),      00000550
     3             (GMDA(  7),       PHIN), (GMDA(  8),        EM),      00000560
     4             (GMDA(  9),       RIPT), (GMDA(109),      XIPT),      00000570
     5             (GMDA(209),      RCURV), (GMDA(309),     RCURZ),      00000580
     6             (GMDA(409),      BNDTX), (GMDA(426),     BNDTB)       00000590
C                                                                        00000600
      DO  2  I = 1,442                                                   00000610
    2 GMDA(I) = 0.0                                                      00000620
C                                                                        00000630
      CALL DECRD (GMDA)                                                  00000640
C                                                                        00000650
      DO  3 I = 1,160                                                    00000660
    3 BMTX(I) = 0.0                                                      00000670
C                                                                        00000680
      IF (BCIT .NE. 1.0) GO TO 5                                         00000690
C                                                   CLOSED APEX          00000700
      OMG0(3,3) = 1.0                                                    00000710
      OMG1 (1,1) = 1.0                                                   00000720
      OMG1 (1,2) = -1.0                                                  00000730
      OMG1 (5,4) = -1.0                                                  00000740
      OMG1 (5,5) = 1.0                                                   00000750
      ALM0(1,1) = 1.0                                                    00000760
      ALM0(2,2) = 1.0                                                    00000770
      ALM0(4,4) = 1.0                                                    00000780
      ALM0(5,5) = 1.0                                                    00000790
      ALM1 (2,1) = 1.0                                                   00000800
      ALM1 (2,2) = 1.0                                                   00000810
      ALM1(3,3) = 1.0                                                    00000820
```

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```
      ALMI(4,4) = 1.0                                                   00000830
      ALMI (4,5) = 1.0                                                  00000840
      GO TO 21                                                          00000850
C                                                                       00000859
    5 IF (BCIT .NE. 10.) GO TO 10                                       00000860
C                                                 SPECIAL BOUNDARY      00000870
      OMGO(1,1) = BNDTX( 1)                                             00000880
      OMGO(1,2) = BNDTX( 2)                                             00000890
      OMGO(2,2) = BNDTX( 3)                                             00000900
      OMGO(3,3) = BNDTX( 4)                                             00000910
      OMGO(4,4) = BNDTX( 5)                                             00000920
      OMGO (5,4) = BNDTX( 6)                                            00000930
      OMGO(5,5) = BNDTX( 7)                                             00000940
      ALMO(1,1) = BNDTX( 8)                                             00000950
      ALMO(2,2) = BNDTX( 9)                                             00000960
      ALMO(3,3) = BNDTX(10)                                             00000970
      ALMO(4,4) = BNDTX(11)                                             00000980
      ALMO(5,5) = BNDTX(12)                                             00000990
      DO  8 IJ = 1,5                                                    00001000
    8 LLO(IJ) = BNDTX(IJ+12)                                            00001010
      GO  TO  21                                                        00001020
C                                                                       00001029
   10 IBMX  =  BCIT                                                     00001030
      IO  =  1                                                          00001040
      IL  =  51                                                         00001050
C                                                 CHOOSE BOUNDARY       00001060
   11 GO TO (21,12,13,14,15,16), IBMX                                   00001070
C                                                 PINNED                00001080
   12 BMTX(IO + 18)  =  1.                                              00001090
      BMTX(IO + 24)  =  1.                                              00001100
      BMTX(IL)  =  1.                                                   00001110
      BMTX(IL + 6)  =  1.                                               00001120
      BMTX(IL + 12)  =  1.                                              00001130
      GO  TO  20                                                        00001140
C                                                 CLAMPED               00001150
   13 BMTX(IL)  =  1.                                                   00001160
      BMTX(IL + 6)  =  1.                                               00001170
      BMTX(IL + 12)  =  1.                                              00001180
      BMTX(IL + 18)  =  1.                                              00001190
      BMTX(IL + 24)  =  1.                                              00001200
      GO  TO  20                                                        00001210
C                                                 FREE                  00001230
   14 BMTX(IO)  =  1.                                                   00001240
```

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```
      BMTX(IO + 6)  =  1.                                          00001250
      BMTX(IO + 12)  =  1.                                         00001260
      BMTX(IO + 18)  =  1.                                         00001270
      BMTX(IO + 24)  =  1.                                         00001280
      GO  TO  20                                                   00001290
C                                          ROLLER  W               00001300
   15 BMTX(IO + 12)  =  1.                                         00001310
      BMTX(IO + 18)  =  1.                                         00001320
      BMTX(IO + 24)  =  1.                                         00001330
      BMTX(IL)  =  1.                                              00001340
      BMTX(IL + 6)  =  1.                                          00001350
      GO  TO  20                                                   00001360
C                                          ROLLER  U               00001370
   16 BMTX(IO)  =  1.                                              00001380
      BMTX(IO + 18)  =  1.                                         00001390
      BMTX(IO + 24)  =  1.                                         00001400
      BMTX(IL + 6)  =  1.                                          00001410
      BMTX(IL + 12)  =  1.                                         00001420
C                                                                  00001429
   20 IF(IO .NE. 1)  GO TO 28                                      00001430
C                                                                  00001439
   21 IF (RCIB .NE. 1.0) GO TO 23                                  00001440
C                                          CLOSED APEX             00001449
      OMGN(3,3) = 1.0                                              00001450
      OMG1 (1,1) = 1.0                                             00001460
      OMG1 (1,2) = -1.0                                            00001470
      OMG1 (5,4) = -1.0                                            00001480
      OMG1 (5,5) = 1.0                                             00001490
      ALMN(1,1)  = 1.0                                             00001500
      ALMN(2,2)  = 1.0                                             00001510
      ALMN(4,4)  = 1.0                                             00001520
      ALMN(5,5)  = 1.0                                             00001530
      ALM1 (2,1) = 1.0                                             00001540
      ALM1 (2,2) = 1.0                                             00001550
      ALM1 (3,3) = 1.0                                             00001560
      ALM1(4,4) = 1.0                                              00001570
      ALM1 (4,5) = 1.0                                             00001580
      GO TO 28                                                     00001590
C                                                                  00001599
   23 IF (RCIB .NE. 10.) GO TO 25                                  00001600
C                                          SPECIAL BOUNDARY        00001609
      OMGN(1,1) = BNDTB( 1)                                        00001610
      OMGN(1,2) = BNDTB( 2)                                        00001620
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
      OMGN(2,2) = BNDTB( 3)                                             00001630
      OMGN(3,3) = BNDTB( 4)                                             00001640
      OMGN(4,4) = BNDTB( 5)                                             00001650
      OMGN (5,4) = BNDTB( 6)                                            00001660
      OMGN(5,5) = BNDTB(7)                                              00001670
      ALMN(1,1) = BNDTB(8)                                              00001680
      ALMN(2,2) = BNDTB( 9)                                             00001690
      ALMN(3,3) = BNDTB(10)                                             00001700
      ALMN(4,4) = BNDTB(11)                                             00001710
      ALMN(5,5) = BNDTB(12)                                             00001720
      DO 24 IJ = 1,5                                                    00001730
   24 LLLN(IJ) = BNDTB(IJ+12)                                           00001740
      GO  TO  28                                                        00001750
C                                                                       00001759
   25 IBMX  =  BCIB                                                     00001760
      IC  =  26                                                         00001770
      IL  =  76                                                         00001780
      GO  TO  11                                                        00001790
C                                                                       00001800
   28 WRITE (6,1000) A , H0, F0, SIG0, POI, FNF, HCIT, HCIB, PFLAG,     00001810
     1 THT, FORNT,                                                      00001811
     2 OMG0, ALM0, LL0, OMGN, ALMN, LLLN                                00001812
C                                                                       00001829
      N = EN                                                            00001830
      GMI = ABS(GIN)                                                    00001840
      NN = N - 1                                                        00001850
      IF (GMI - 2.0) 30, 35, 50                                         00001860
C                                                                       00001870
C                 CONE - CYLINDER                           **          00001880
C                                                                       00001890
   30 IF (PFLAG .NE. 0.0) WRITE(6,31)       N, RA1, AXL, ANX            00001900
C                                                                       00001910
   31 FORMAT (1H1,39X,33HGEOMETRY DATA FOR CONE - CYLINDER //35X,22HNU  00001920
     1ER OF STATIONS -  ,I4//6X,7HRA1   =,1PE13.4,7X,7HAXL   =,E13.4,7X,00001930
     2 7HANX   =,F13.4)                                                 00001940
C                                                                       00001950
      DEL =  AXL/(FN - 1.0)                                             00001960
      SINFI  = SIND(ANX)                                                00001970
      COSFI  = COSD(ANX)                                                00001980
      XSI(1) = 0.0                                                      00001990
      WTHX(1) = A0 * COSFI/RA1                                          00002000
      WFFX(1) = 0.0                                                     00002010
      RHOX(1) = RA1/A0                                                  00002020
```

```
      R(1) = RA)                                                        00002030
      DO 32 I = 2,N                                                     00002040
      R(I)  = R(I-1) + DEL * SINFI                                      00002050
      XSI(I) = XSI(I-1) + DEL * COSFI                                   00002060
      WTHX(I) = A0 * COSFI/R(I)                                         00002070
      WFEX(I) = 0.0                                                     00002080
   32 RHOX(I) = R(I)/A0                                                 00002090
      GO TO 95                                                          00002100
C                                                                       00002110
C                    SPHERE - TOROID                            **      00002120
C                                                                       00002130
   95 IF (PFLAG .NE. 0.0)  WRITE (6,37)  N, RC, ROFF, PHI0, PHIN        00002140
C                                                                       00002150
   37 FORMAT (1H1,39X,33HGEOMETRY DATA FOR SPHERE - TOROID //35X,22HNUMB00002160
     1ER OF STATIONS -  ,I4//6X,7HRC     =,1PE13.4,7X,7HROFF   =,E13.4,7X,00002170
     2 7HPHI0   =,E13.4,7X,7HPHIN   =,E13.4 )                           00002180
C                                                                       00002190
      ANGSP = PHIN - PHI0                                               00002200
      DEL =  ANGSP/(EN - 1.0)                                           00002210
      AM = 1.0                                                          00002220
      AMU = SIGN(AM,DEL)                                                00002230
      XSI(1) =  0.0                                                     00002240
      BPHI = PHI0                                                       00002250
      BSINP = SIND(PHI0)                                                00002260
      BCOSP = COSD(PHI0)                                                00002270
      R(1) = RC * BSINP + ROFF                                          00002280
      DO 40 I = 1,NN                                                    00002290
      APHI = BPHI + DEL                                                 00002300
      ASINP = SIND(APHI)                                                00002310
      ACOSP = COSD(APHI)                                                00002320
      R(I+1) = R(I) + RC * (ASINP - BSINP)                              00002330
      XSI(I+1) = XSI(I) + RC * (BCOSP - ACOSP)                          00002340
      WFEX(I) = A0/RC * AMU                                             00002350
      IF (ROFF .EQ. 0.0) GO TO 38                                       00002360
      WTHX(I) = A0 * BSINP/R(I)                                         00002370
      GO TO 39                                                          00002380
   38 WTHX(I) = WFEX(I)                                                 00002390
   39 RHOX(I) = R(I)/A0                                                 00002400
      BPHI = APHI                                                       00002410
      BSINP = ASINP                                                     00002420
      BCOSP = ACOSP                                                     00002430
   40 CONTINUE                                                          00002440
C                                                                       00002450
```

```
      DFL = ABS(DFL)                                                    00002460
      WFEX(N) = AO/RC*ANO                                               00002470
      IF (ROFF .EQ. 0.0) GO TO 45                                       00002480
      WTHX(N) = AO * HSINP /R(N)                                        00002490
      GO TO 46                                                          00002500
   45 WTHX(N) = WFEX(N)                                                 00002510
      IF (BCIB .EQ. 1.0) GO TO 47                                       00002520
   46 RHOX(N) = R(N)/AO                                                 00002530
      GO TO 48                                                          00002540
   47 RHOX(N) = 0.0                                                     00002550
   48 DFL = DFL * RC * 0.01745329                                       00002560
      GO TO 95                                                          00002570
C                                                                       00002580
   50 IF (GMT .GT. 3.0) GO TO 60                                        00002590
C                                                                       00002600
      WRITE (6,55)                                                      00002610
   55 FORMAT (1H1,43HARBITRARY FUNCTIONS CANNOT BE HANDLED, YET. )      00002620
C                                                                       00002630
      GO TO 140                                                         00002640
C                                                                       00002650
C                     GENERAL DISCRETE POINTS                   **      00002660
C                                                                       00002670
   60 M  =  EM                                                          00002680
      MM = M - 1                                                        00002690
      MM2 = M- 2                                                        00002700
C                                                                       00002710
      IF (PFLAG .NE. 0.0) WRITE(6,62)      N, (RIPT(I), XIPT(I), I = 1,M)00002720
C                                                                       00002730
   62 FORMAT (1H1,39X,31HGEOMETRY DATA - DISCRETE POINTS //35X,22HNUMBER00002740
     1 OF STATIONS -   ,I4//16X,1HR,16X,2HX1//(3X,1P2E20.7) )           00002750
C                                                                       00002760
      SARB(1) = 0.0                                                     00002770
      IF(GIN .LT. 0.) GO TO 77                                          00002780
      DO 75 IL = 1,MM                                                   00002790
      SURB = 0.0                                                        00002800
      DLT = XIPT(IL+1) - XIPT(IL)                                       00002810
      K = 10                                                            00002820
      AK = K                                                            00002830
      DDL = DLT/AK                                                      00002840
      KP1 = K + 1                                                       00002850
      DO 65 J1 = 1,KP1                                                  00002860
      AJ1 = J1 - 1                                                      00002870
      XJ(J1) = XIPT(IL) + AJ1 * DDL                                     00002880
```

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```
   65 CONTINUE                                                        00002890
C                                                                     00002900
      CALL CODIMA (KP1,XJ, RRJ, XIPT, RIPT, M, 1.0)                   00002910
      DO  69 I = 2,K                                                  00002920
   69 RJ(I) =  (RRJ(I-1) + RRJ(I) + RRJ(I+1) )/3.0                    00002930
      RJ(1) = RRJ(1)                                                  00002940
      RJ(KP1) = RRJ(KP1)                                              00002950
C                                                                     00002960
      DO 70 JR = 1,K                                                  00002970
      DLR(JR) = RJ(JR+1) - RJ(JR)                                     00002980
      DLS     =   SQRT(DLR(JR)**2 + DUL**2)                           00002990
   70 SURB = SURB + DLS                                               00003000
      SARB(IL+1) = SARB(IL) + SURB                                    00003010
   75 CONTINUF                                                        00003020
      GO TO 80                                                        00003030
   77 DO 78 I = 1,M                                                   00003040
   78 SARB(I) = XIPT(I)                                               00003050
   80 DEL = SARB(M) /(EN - 1.0)                                       00003060
C                                                                     00003070
      SURF(1) = 0.0                                                   00003080
      DO 82 I = 1,NN                                                  00003090
   82 SURF(I+1) = SURF(I) + DLL                                       00003100
      CALL CODIMA(N, SURF,RCRV, SARB, RCURV, M, 1.0)                  00003120
      CALL CODIMA(N,SURF, RCRZ, SARB, RCURZ, M, 1.0)                  00003130
C                                                                     00003140
      CALL CODIMA (N,SURF, R, SARB, RIPT, M, 1.0)                     00003150
C                                                                     00003160
      CALL CODIMA (N, SURF, XSI, SARB, XIPT, M, -1.0)                 00003170
      MLN = N - 2                                                     00003180
      NSM = 1                                                         00003190
   84 DO 85 I = 3,MLN                                                 00003200
      RR(I) = (-3.*R(I-2) + 12.*R(I-1) + 17.*R(I) + 12.*R(I+1) - 3. * 00003210
     1 R(I+2) )/ 35.0                                                 00003220
   85 CONTINUF                                                        00003230
      RR(NN) = R(NN)                                                  00003240
      RR(2) = R(2)                                                    00003250
      RR(N) = R(N)                                                    00003260
      RR(1) = R(1)                                                    00003270
      IF (NSM .EQ. 25) GO TO 88                                       00003280
      NSM = NSM + 1                                                   00003290
      DO  87 I = 1,N                                                  00003300
   87 R(I) = RR(I)                                                    00003310
      GO TO  84                                                       00003320
```

```
   88 RHOX(1) = RR(1)/AO                                                 00003330
      DELSQ = DEL * DEL                                                  00003340
      DO 89 I = 1,NN                                                     00003350
   89 RHOX(I+1) = RR(I+1) /AO                                            00003360
      GO TO 110                                                          00003370
C                                                                        00003380
C                      COMPUTE GAMA                             **       00003390
C                                                                        00003400
   95  DEL = DEL/ AO                                                     00003410
       DELSQ = DEL * DEL                                                 00003420
       DO 105 I = 1,N                                                    00003430
      DENM = 12. * RHOX(I) * DEL                                         00003440
      DENMP= 2. * RHOX(I) * DEL                                          00003450
      IF(RHOX(I) .EQ. 0.)  GO TO 97                                      00003460
      IF (I .NE. 1) GO TO 98                                             00003470
      IF (BCIT .EQ. 1.0) GO TO 103                                       00003475
      GAMA(I) = (3.*(RHOX(I+1) - RHOX(I)) + RHOX(I+1) - RHOX(I+2))/DENMP00003480
      GO TO 105                                                          00003490
   97 GAMA(I)  =  0.0                                                    00003500
      GO  TO  105                                                        00003510
   98 IF (I .EQ. N) GO TO 100                                            00003520
      IF (I .EQ. 2) GO TO 99                                             00003530
      IF (I .EQ. N-1) GO TO 99                                           00003540
      GAMA(I) = (RHOX(I-2) - 8. *(RHOX(I-1) -      RHOX(I+1))- RHOX(I+2)00003550
     1 )/DENM                                                            00003560
      GO TO 105                                                          00003570
   99 GAMA(I) = (RHOX(I+1) - RHOX(I-1)) /DENMP                           00003580
      GO TO 105                                                          00003590
  100 IF (BCIB .EQ. 1.0)  GO TO 103                                      00003595
      GAMA(I) =(3.*(RHOX(I)-RHOX(I-1)) + RHOX(I-2) - RHOX(I-1)) /DENMP   00003600
      GO  TO  105                                                        00003602
  103 GAMA(I)  =  0.                                                     00003608
  105 CONTINUE                                                           00003610
       GO TO 123                                                         00003620
C                                                                        00003630
  110 DO 115 I = 1,N                                                     00003640
      WEEX(I) = AO/RCRV(I)                                               00003650
      WTHX(I) = AO/RCRZ(I)                                               00003660
      IF (RHOX(I) .EQ. 0.0) GO TO 113                                    00003670
      PRO = (RHOX(I) * WTHX(I))**2                                       00003680
      IF (PRO .GT. 1.0) GO TO 114                                        00003690
      GAMA(I) = SQRT(1.-PRO)/RHOX(I)                                     00003700
      GO TO 115                                                          00003710
```

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```
  113 GAMA(I) = 0.0                                                     00003720
      GO TO 115                                                         00003730
  114 GAMA(I) = 0.0                                                     00003740
  115 CONTINUE                                                          00003750
C                                                                       00003759
  123 DO 127 I = 1,N                                                    00003760
      WFDNM  =  2. * DFL                                                00003770
      IF (I .NE. 1) GO TO 124                                           00003780
      WFEPX(I) = (4. * WFEX(I+1) - 3. * WFEX(I) - WFEX(I+2)) /WFDNM     00003790
      GO TO 127                                                         00003800
  124 IF (I .EQ. N) GO TO 126                                           00003810
      WFEPX(I) = (WFEX(I+1) - WFEX(I-1)) /WFDNM                         00003820
      GO TO 127                                                         00003830
  126 WFEPX(I) = (WFEX(I-2) + 3. * WFEX(I) - 4. * WFEX(I-1)) /WFDNM     00003840
  127 CONTINUE                                                          00003850
C                                                                       00003859
      WRITE ( 4) THX, WFEX, GAMA, RHOX, WFEPX                           00003860
C                                                                       00003870
  129 IF (PFLAG .EQ. 0.0) GO TO 140                                     00003880
      WRITE (6,130) DFL, (I, R(I), XSI(I), THX(I), WFEX(I), RHOX(I),    00003890
     1 GAMA(I), I = 1,N)                                                00003900
C                                                                       00003910
  130 FORMAT (1H-, 5X, 7HDFL   =,1PE13.4 //                             00003920
     1              3X,1HI,9X,4HR(I),12X,5HXI(I),1 X,8H (THETA),11X,    00003921
     2 5HW(XI),11X,7HRHOX(I),1 X,7HGAMA(I) //(I4, 1P6E17.7) )           00003922
C                                                                       00003940
  140 RETURN                                                            00003950
C                                                                       00003959
 1000 FORMAT(1H1,4/X,12HGENERAL DATA/// 3X,7HA      =,1PE13.4, 8X,7HHO   00004120
     1 =,E13.4, 8X,7HEO     =,E13.4, 8X,7H IG    =,E13.4// 3X,7HPOI    =,  00004121
     2 E13.4, 8X,7HENF    =,E13.4, 8X,7HBCIT   =,E13.4, 8X,7HBCIB   =,   00004122
     3 E13.4//3X,7HPFLAG =, E13.4 //                                    00004123
     4       //6X,2 HPRINT ANGLES (THT) - // 24X,6E13.4 //6X,33HFOURIER H00004124
     5ARMONIC POINTS (FPRNT) - // 24X, 4E13.4                           00004125
     6                                   ///1H-,45X,17HBOUNDAR00004126
     7Y MATRICES /6X,15HTOP BOUNDARY **// 6X,5HOMEGA /5(5E17.7/)// 6X,   00004127
     8 6HLAMBDA /5(5E17.7/)// 6X,3HL -/ 5E17.7 ///6X,18HBOTTOM BOUNDARY 00004128
     9** // 6X,5HOMEGA /5(5E17.7/)// 6X,6HLAMBDA /5(5E17.7/)// 6X,3HL -/00004129
     X 5E17.7  )                                                        00004130
      END                                                               00009999
```

3.11d DATLYR Subroutine (STIFF)

```
$IBFTC STIFF                                                            00000010
C                 FOURIER STIFFNESS COEFFICIENTS GENERATOR      * *     00000020
C                                                                       00000030
      SUBROUTINE DATLYR                                                 00000040
C                                                                       00000110
C     *** STIFFNESS COEFF. ARE STORED IN SECTIONS OF ALL FOURIER        00000111
C         COMPONENTS /MERIDIONAL STATION, UP TO BLOCKS OF 200           00000112
C                                                                       00000120
      DIMENSION  COFFC(3000)                                            00000130
      DIMENSION  SCB1(200), SCB2(200), SCB3(200), SCG1(200), SCG2(200), 00000140
     1 SCG3( 200), SCD1(200), SCD2(200), SCD3(200), SCG13(200),         00000141
     2 SCNTST(200), SCNTTH(200), SCMTST(200), SCMTTH(200), DCK3(200)    00000142
C                                                                       00000179
      COMMON  GDA(25), DFL, N, NNF, NTH,                                00000180
     1 GMTX(160)                                                        00000190
C                                                                       00000200
C                                                                       00000210
      EQUIVALENCE (GDA( 1),    A0),              (GDA( 2),   H0),       00000220
     1            (GDA( 3),    E0),              (GDA( 4), SIG0),       00000230
     2            (GDA( 5),  POT),               (GDA( 6),  ENF),       00000240
     3            (GDA( 7), BCIT),               (GDA( 8), BCIB),       00000250
     4            (GDA( 9),PFLAG),                                      00000251
     5                                           (GDA(12),  THT),       00000252
     6            (GDA(18),FPRNT)                                       00000253
C                                                                       00000260
C                                                                       00000299
      EQUIVALENCE (COEFC(   1),  SCB1),         (COEFC( 201),  SCB2),  00000300
     1            (COEFC( 401),  SCB3),         (COEFC( 601),  SCG1),  00000301
     2            (COEFC( 801),  SCG2),         (COEFC(1001),  SCG3),  00000302
     3 (COEFC(1201),  SCD1), (COEFC(1401),  SCD2), (COEFC(1601),  SCD3),00000303
     4 (COEFC(1801), SCG13), (COEFC(2001),SCNTST), (COEFC(2201),SCNTTH),00000304
     5 (COEFC(2401),SCMTST), (COEFC(2601),SCMTTH), (COEFC(2801),  DCK3) 00000305
C                                                                       00000329
      IF(PFLAG .LT. 0.)  WRITE(6,10)                                    00000331
   10 FORMAT(1H1/6X, 96HCHECKPRINT OF COEFC BLOCKS STORED IN GROUPS OF (00000332
     12*ENF) PER MERIDIONAL STATION.  THE COEFFICIENTS /107H PRINTED ARE00000333
     2 SCB1, SCD1, SCNTST, SCMTST, DCK3 (IN THAT ORDER) AND ARE SEPARATE00000334
     3D FROM EACH OTHER BY THE      / 21H THREE ...... FIELDS.  /// )   00000335
C                                                                       00000380
      ENTH  =  90.                                                      00000390
      H02 = H0 * H0                                                     00000400
      SS3 = 2./3.1415927                                                00000410
      NTH  = ENTH                                                       00000420
```

```
      NNF  =  FNF
      NNF2  = 2 * NNF
      IN = 1
C                  DETERMINE SIZE OF BLOCK                        **
C
      MNF  = N * NNF2
   40 IF (MNF .GT. 200) GO TO 50
C                                             LESS THAN ONE BLOCK MORE
      LN = N
      GO TO 60
   50 IF (MNF .LT. 400) GO TO 55
C                                          AT LEAST 2 FULL BLOCKS MORE
      LN = 200/NNF2
      GO TO 58
C
C                                  GREATER THAN ONE BLOCK. LESS THAN TWO
C                               AVOID HAVING ONLY TWO STATIONS IN A BLOCK.
C
   55 LN = 100/NNF2
   58 LN = IN + LN - 1
C
   60 DELTH = 3.1415927/ ENTH
C
C                                           ZERO COEFFICIENT AREA
   63 DO  65 I = 1.2000
   65 COEF(I) = 0.0
C
   70 DO 100 I = IN. LN
C                                    ESTABLISH MERIDIONAL DISTANCE
      FI = I - 1
      DEL = FI * DEL
C
      K1 = NNF2 * (I - IN)
      DO 100  NN = 1.NNF2
      K2 = K1 + NN
      FNN = NN - 1
C
   75 DO 95 J = 1.NTH
      FJ = J - 1
      ZTA = FJ * DELTH + DELTH * 0.5
      IF (NN .EQ. 1) GO TO 90
C
```

```
C                                           OTHER FOURIER COMPONENTS      00000839
   80 SCB1(K2) = SCB1(K2) + BBB(PEL,ZTA)      * COS (ENN *  ZTA)          00000840
      SCNTSI(K2) = SCNTSI(K2) + ENTI(PEL,ZTA) * COS(ENN * ZTA)            00000850
      SCMTSI(K2) = SCMTSI(K2) + EMTT(PEL,ZTA) * COS(ENN * ZTA)            00000855
      SCD1(K2) = SCD1(K2) + DDD(ZTA)          * COS (ENN *  ZTA)          00000860
      DCK3(K2) =DCK3(K2)+  DKK3(PEL,ZTA)   * COS(ENN* ZTA)                00000866
      GO TO 95                                                            00000870
C                                           FIRST FOURIER COMPONENT       00000879
   90 SCB1(K2) = SCB1(K2) + BBB(PEL,ZTA) / 2.0                            00000880
      SCNTSI(K2) = SCNTSI(K2) + ENTI(PEL,ZTA) / 2.0                       00000883
      SCMTSI(K2) = SCMTSI(K2) + EMTT(PEL,ZTA) / 2.0                       00000886
      SCD1(K2) = SCD1(K2) + DDD(ZTA) / 2.0                                00000890
      DCK3(K2) =DCK3(K2) + DKK3(PEL,ZTA)/2.0                              00000896
   95 CONTINUE                                                            00000900
C                                                                         00000910
C                                               NORMALIZE                 00000919
      S3 = SS3/(EO * HO)                                                  00000920
      SCB1(K2) = S3 * DELTH * SCB1(K2)                                    00000930
      S4 = S3 * AO*AO                                                     00000931
      DCK3(K2) = S4 * DELTH * DCK3(K2)                                    00000934
      S3 = SS3 /(SIGO * HO)                                               00000935
      SCNTSI(K2) = S3 * DELTH * SCNTSI(K2)                                00000940
      S3 = SS3 * AO /(SIGO * HO2 * HO)                                    00000945
      SCMTSI(K2) = S3 * DELTH * SCMTSI(K2)                                00000950
      S3 = SS3/(EO * HO2 * HO)                                            00000955
      SCD1(K2) = S3 * DELTH * SCD1(K2)                                    00000960
C                                                                         00000970
   98 SS2 = (1. - PO1) / 2.                                               00000980
      SCG13(K2) = SS2 * SCD1(K2)                                          00000990
      SCG1(K2) = SS2 * SCB1(K2)                                           00001000
      SCB2(K2) = SCB1(K2)                                                 00001010
      SCB3(K2) = PO1 * SCB1(K2)                                           00001020
      SCG2(K2) = SS2 * SCB1(K2)                                           00001030
      SCG3(K2) = SCG1(K2)                                                 00001040
      SCD2(K2) = SCD1(K2)                                                 00001050
      SCD3(K2) = PO1 * SCD1(K2)                                           00001060
  100 CONTINUE                                                            00001120
C                                                                         00001130
      WRITE ( 9) LN, IN, COFFC                                            00001140
      NX  =  (LN - IN + 1) * NNF2                                         00001145
      XX  =  GDA(25)                                                      00001146
      IF(PFLAG .LT. 0.)                                                   00001149
     XWRITE (6,105)  IN, LN, (SCB1(I), I=1,NX), XX, XX, XX, (SCD1(I),     00001150
```

```
    1 I=1,NX), XX, XX, XX, (CNDS1(I), I=1,NX), XX, XX, XX, (CDM1 I(I),
    2 I=1,NX), XX, XX, XX, (DCK3(I), I=1,NX)
  105 FORMAT(/10X,11HFOR STATION, I3,16H THROUGH STATION, I4///
     1       ( 1P6F17.7) )
C
      IF (LN .EQ. N) GO TO 110
      IN = LN + 1
      NCN = N - LN
      MNF = NCN * NNE2
      GO TO 40
  110 RETURN
C
      END
```

3.11e DATLD Subroutine (LOAD)

```
$IBFTC LOAD                                                             00000010
C                 FOURIER LOAD COEFFICIENTS GENERATOR BY FUNCTIONS ONLY 00000020
C                                                                       00000030
      SUBROUTINE  DATLD                                                 00000040
C                                                                       00000050
C                                                                       00000060
      DIMENSION  PFF(10,50), PTH(10,50), PN(10,50)                      00000340
C                                                                       00000430
      EQUIVALENCE (GDA( 1),   AO),             (GDA( 2),   HO),         00000440
     1            (GDA( 3),   EO),             (GDA( 4), SIGO),         00000441
     2            (GDA( 5),  POI),             (GDA( 6),  ENF),         00000442
     3            (GDA( 7), BCIT),             (GDA( 8), BCIB),         00000443
     4            (GDA( 9),PFLAG),                                      00000444
     5                                         (GDA(12),  THT),         00000445
     6            (GDA(18),FPRNT)                                       00000446
C                                                                       00000449
      COMMON  GDA(25), DFL, N, NNF, NTH,                                00000490
     1 BMTX(160)                                                        00000500
C                                                                       00000510
C                 INITIALIZE *            *           *          *      00000520
C                                                                       00000530
      NAB = 0                                                           00000540
      SS3 = 2. /3.1415927                                               00000560
      S3 = SS3 * AO/(SIGO * HO)                                         00000570
C                                                                       00000580
      DO 20 I = 1,50                                                    00000590
      DO 20 K = 1,10                                                    00000600
      PFF(K,I) = 0.0                                                    00000610
      PTH(K,I) = 0.0                                                    00000630
      PN(K,I)  = 0.0                                                    00000650
   20 CONTINUE                                                          00000670
C                                                                       00000680
      IF(PFLAG .LT. 0.)  WRITE(6,30)                                    00000730
   30 FORMAT(1H1/6X, 98HCHECKPRINT OF LOAD COFF. STORED IN GROUPS OF ALL00000740
     1 ENF PER MERIDIONAL STATION.  THE COEFFICIENTS ARE  / 81H PFF, PTH00000741
     2, PN (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY ****** F00000742
     3IELDS.  ///)                                                      00000743
      NT = N                                                            00000770
C                                                                       00000790
C                                            SPECIAL  FUNCTIONS         00000800
   80 FT = 0.0                                                          00000810
      NI1 = 1                                                           00000820
      NI2  =  N                                                         00000830
```

```
      FNTH  =  NTH                                                      00000840
      DFLTH = 3.1415927 / FNTH                                          00000850
C                                                                       00000870
C                EACH BLOCK OF LOADS CANNOT CONTAIN MORE THAN 50 STAS.  00000880
C                                                                       00000890
      IF (NI .GT. 50) NI = 50                                           00000900
   70 DO 100 I = 1,NI                                                   00000910
      FI = FI + 1.0                                                     00000920
      PEL = (FI - 1.0) * DFL                                            00000930
C                                                                       00000939
      DO 100 NN = 1,NNF                                                 00000940
      FNN = NN- 1                                                       00000950
C                                                                       00000970
      DO 95 J = 1,NTH                                                   00000980
      FJ = J - 1                                                        00000990
      ZTA = EJ * DELTH + DFLTH * 0.5                                    000010
      IF (NN .EQ. 1)  GO TO 90                                          00001017
C                                                                       00001020
      PTH(NN,I) = PTH(NN,I) + PPPH(PEL,ZTA) *  SIN(FNN * (ZTA-1.5707963))00001030
      PFF(NN,I) = PFF(NN,I)  + PPPF(PEL,ZTA) * COS(FNN * ZTA)           00001040
      PN(NN,I) = PN(NN,I) + PPPN(PEL,ZTA) * COS(FNN * ZTA)              00001060
      GO TO 95                                                          00001070
C                                                                       00001079
   90 PTH(NN,I) = PTH(NN,I) + PPPH(PEL,ZTA) /2.                         00001080
      PFF(NN,I) = PFF(NN,I) + PPPF(PEL,ZTA) /2.                         00001090
      PN(NN,I) = PN(NN,I) + PPPN(PEL,ZTA) / 2.                          00001100
   95 CONTINUE                                                          00001120
C                                                                       00001110
      PTH(NN,I) = S3 * DELTH * PTH(NN,I)                                0000114
      PFF(NN,I) = S3 * DFLTH * PFF(NN,I)                                000011
      PN(NN,I) = S3 * DELTH * PN(NN,I)                                  00001160
  100 CONTINUE                                                          00001170
C                                                                       00001180
      WRITE ( 3)  PFF, PTH, PN                                          00001190
  107 XX  =  GOA(25)                                                    00001220
      IF(N .GT. 50 .AND. NAF.EQ. 0)  NI2 = 50                           00001222
      IF(PFLAG .LT. 0.)                                                 00001229
     WRITE (6,108) NI1, NI2, ((PFF(NN,I), NN=1,NNF), I=1,NI), XX, XX,   0000123
     1XX, ((PTH(NN, I), NN=1,NNF), I=1,NI), XX, XX, XX, ((PN(NN,I), NN=1,00001231
     2NNF), I=1,NI)                                                     00001232
  108 FORMAT(/10X,11HFOR STATION, I3,16H THROUGH STATION, I4///         00001235
     1       ( 1P6E17.7) )                                              00001236
C                                                                       00001238
```

```
      NAB = NAB + NI                                                    00001239
      IF (NAB .EQ. NI) GO TO 600                                        00001240
C                                                                       00001250
C                MORE THAN 50 STATIONS TO STORE                 *       00001260
C                                                                       00001270
      NI = N - NI                                                       00001280
      NI1  =  51                                                        00001281
      NI2  =  N                                                         00001282
      DO 115 I = 1,50                                                   00001290
      DO 110 J = 1,10                                                   00001300
      PTH(J,I) = 0.0                                                    00001310
      PFE(J,I) = 0.0                                                    00001320
  110 PN(J,I) = 0.0                                                     00001330
  115 CONTINUE                                                          00001340
C                                                                       00001350
      GO TO 70                                                          00001360
C                                                                       00003000
  600 END FILE 3                                                        00003010
      REWIND 3                                                          00003020
C                                                                       00003030
      RETURN                                                            00003040
  620 FORMAT (1H-// (10X, 1P5F17.7))                                    00003050
      END                                                               00003060
```

3.11f PANDX Subroutine (PEANDX)

```
$IBFTC PEANDX                                                           00000010
C         GENERATES THE 'P' AND 'X' MATRICES                    **      00000020
C             NOTE    RECURSION TERMS ARE ALSO GENERATED        **      00000030
C                                                                       00000040
      SUBROUTINE  PANDX                                                 00000050
C                                                                       00000060
C     A0          REFERENCE LENGTH (IN)                                 00000070
C     H0          REFERENCE THICKNESS (IN)                              00000080
C     E0          REFERENCE YOUNGS MODULUS  (PSI)                       00000090
C     SIGO        REFERENCE STRESS  (PSI)                               00000100
C     NNF         NO. OF TERMS IN THE FOURIER EXPANSION.                00000110
C     LAM         LAMBDA  =  H0 /A0                                     00000120
C     WFE         OMEGA (XI)                                            00000130
C     WTH         OMEGA (THETA)                                         00000140
C      ARRAYS USED                                                      00000150
C          COEFC   -   CONTAINS STIFF. COEFF. FROM DATLYR               00000160
C          P1SCB1  -   TEMPORARY STORAGE                                00000170
C          P2SCB1  -   FOR STIFFNESS COEFF. (B1)                        00000180
C      PANDX FLAGS                                                      00000190
C          IRTE .NE. 1   FIRST STATION  -  NOT FIRST BLOCK              00000200
C          IRTE .EQ. 1   LAST STATION - PREVIOUS BLOCK                  00000210
C          IFGFG = 10   F, G, H, PE  HAVE NOT BEEN COMPLETED, YET.      00000220
C          IFGFG = 0    P AND X  HAVE BEEN COMPUTED FOR IRTE = 1.       00000230
C          IFGFG = 1    P AND X  COMPUTED.  INCREMENT STA. INDEX.       00000240
C          IRSFG = 10   R, S, LT,  HAVE NOT BEEN COMPLETED.             00000250
C          IRSFG = 1   INITIAL BOUNDARY COMPUTED.                       00000260
C          IRSFG = 0   TERMINAL BOUNDARY COMPUTED.                      00000270
C      COUNTERS  -                                                      00000280
C          MM   - ABSOLUTE STATION NUMBER.        *         *           00000290
C          I    - STATION NO. WITHIN EACH BLOCK OF STIFF. COEFF.        00000300
C          MMN  - STATION NO. WITHIN BLOCK OF LOADS.                    00000310
C          IFLG - STIFF. COEFF. BLOCK. *          *                     00000320
C                                                                       00000330
      EQUIVALENCE  (BMTX(  1), OMG0),              (BMTX( 26), OMGN),   00000340
     1             (BMTX( 51), ALM0),              (BMTX( 76), ALMN),   00000350
     2             (BMTX(101), OMG1),              (BMTX(126), ALM1),   00000360
     3             (BMTX(151),  LL0),              (BMTX(156), LLLN)    00000370
C                                                                       00000379
      EQUIVALENCE (GDA( 1),   A0),              (GDA( 2),   H0),        00000380
     1            (GDA( 3),   E0),              (GDA( 4), SIG0),        00000390
     2            (GDA( 5),  POI),              (GDA( 6),  ENF),        00000400
     3            (GDA( 7), BCIT),              (GDA( 8), BCIB),        00000410
     4            (GDA( 9),PFLAG),                                      00000411
```

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     5                                   (GDA(12),  THT),           00000412
     6         (GDA(18),PRNT)                                       00000413
C                                                                   00000419
      EQUIVALENCE (COFFC(   1),  SCB1),          (COEFC( 201),  SCB2), 00000420
     1            (COEFC( 401),  SCB3),          (COEFC( 601),  SCG1), 00000421
     2            (COEFC( 801),  SCG2),          (COEFC(1001),  SCG3), 00000422
     3 (COEFC(1201),  SCD1), (COEFC(1401),  SCD2), (COEFC(1601),  SCD3),00000423
     4 (COEFC(1801), SCG13), (COEFC(2001),SCNTSI), (COEFC(2201),SCNTTH),00000424
     5 (COEFC(2401),SCMTSI), (COEFC(2601),SCMTTH), (COEFC(2801),  DCK3) 00000425
C                                                                   00000500
      DIMENSION  WTHX(100), WFEX(100), RHOX(100), GAMA(100), WFEPX(100) 00000510
      DIMENSION  ALMO(5,5), ALMN(5,5), OMGO(5,5), OMGN(5,5)         00000520
      DIMENSION  ALM1(5,5), OMG1(5,5)                               00000530
      REAL  LLO(5),  LLLN(5),                    MFE(10), MTP(10)   00000540
      DIMENSION  P1SCB1(20), P2SCB1(20), P1SCD1(20), P2SCD1(20),    00000550
     1  TFE(10), P1SG13(20), P2SG13(20), P1ENT(20), P2ENT(20),      00000560
     2  TTP(10), P1SCG1(20), P2SCG1(20), P1EMT(20), P2EMT(20),      00000570
     3  P2DCK3(20), PFE50(10), PTH50(10), PN50(10)                  00000571
      DIMENSION   PFF(10, 50),   PTH(10, 50),   PN(10, 50)          00000580
      DIMENSION  P(50,50), X(50)                                    00000600
C                                                                   00000610
      DIMENSION  COEFC(3000)                                        00000620
      DIMENSION  SCB1(200), SCB2(200), SCB3(200), SCG1(200), SCG2(200), 00000630
     1 SCG3( 200), SCD1(200), SCD2(200), SCD3(200), SCG13(200),     00000631
     2 SCNTSI(200), SCNTTH(200), SCMTSI(200), SCMTTH(200), DCK3(200) 00000632
C                                                                   00000670
      COMMON  GDA(25), DEL, N, NNF, NTH,                            00000680
     1 RMTX(160)                                                    00000690
C                                                                   00000699
      REAL   LAM, LAMO2, LAM2O2, LAM2O4, LAM2O8, LAM2, KORO, KORO2, 00000700
     1         MFFTK, MTHTK, MFETP,      LLI                        00000710
C                                                                   00000719
      COMMON /PXCMN/     MM, LLN, I, IFLG, LN, IRSFG, IFGFG,        00000720
     1 RR1KJ, RR2KJ, RR3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ, 00000721
     2 GG13KJ, TFETK, TTHTK, MFETK, MTHTK, BB1P, BB3P, GG1P, GG2P,  00000722
     3 DD1P, DD3P, GG13P, TFETP, MFETP, OMG(5,5), ALM(5,5), LLI(5), 00000723
     4 WTH, WFE, GAM, RHO, WFEP, LAM, LAM2, LAMO2, LAM2O2, LAM2O4,  00000724
     5 LAM2O8, GAM2, WTMWF, WTMWF2, WFWT, PTHK, PNK, PFEK, P, X,    00000725
     6 DCK1KJ, DCK2KJ, DCK3KJ                                       00000726
C                                                                   00000789
      COMMON /BLOCK1/  EMM2(50,50)                                  00000790
      COMMON /BLOCK2/  EMM3(50)                                     00000800
C                                                                   00000810
```

```
C
      IF(PFLAG .EQ. -1.E+10)  WRITE (6,340)
C                 READ GEOMETRY PARAMETERS FROM TAPE 4, FIRST FILE. (100)
C                 THIS TAPE IS WRITTEN IN GEOM AND BACKSPACED IN DATLNK
      READ  ( 4) WTHX, WFEX, GAMA, RHOX, WFEPX
C
C                 INITIALIZE *        *          *          *
      N2 = 2 * NNF
      MMN = 0
      IFLG = 0
C                 READ PRESSURES (10,50) FROM TAPE 3, FIRST FILE.
C                 TAPE 3 WRITTEN AND REWOUND IN DATLD SUBROUTINE
      READ ( 3)  PFE, PTH, PN
C
C                 READ STIFFNESS COEFF (200) FROM TAPE 9. THIS TAPE IS
C                 WRITTEN IN DATLYR AND REWOUND IN DATLNK AND MAIN
C                 IN  -  INITIAL STATION IN BLOCK
C                 LN  -  LAST STATION IN BLOCK
   10 READ  ( 9) LN, IN, COE.C
C
      IRTE = 1
      MM = IN - 1
      IFLG = IFLG + 1
      LLN = LN - IN + 1
      I = 0
      KK = NNF
      DEL2 = 2. * DEL
C
   20 I = I + 1
      MM = MM + 1
      MMN = MMN + 1
      IF (MM .NE. 51)  GO TO 23
      DO  21      IX = 1,KK
      PFE50(IX)   =  PFE(IX,50)
      PTH50(IX)   =  PTH(IX,50)
   21 PN50(IX)    =  PN(IX,50)
      READ ( 3)  PFE, PTH, PN
      MMN = 1
      REWIND 3
C
   23 DO 9998 J = 1,KK
C
C                 FSTABLISH BOUNDARY CONDITIONS ARRAY.        *
```

```
C                                                                       00001090
      IF (MM .NE. 1) GO TO 33                                           00001100
      IF (J .EQ. 1) GO TO 31                                            00001110
      IF (BCIT .NE. 1.0) GO TO 31                                       00001120
      IF (J .GT. 2) GO TO 29                                            00001130
C                                          CLOSED APEX, 2ND HARMONIC    00001139
   27 DO 28 KN = 1,5                                                    00001140
      LLI(KN) = 0.0                                                     00001145
      DO 28 JJ = 1,5                                                    00001150
      OMG(KN,JJ) = OMGI(KN,JJ)                                          00001160
   28 ALM(KN,JJ) = ALMI(KN,JJ)                                          00001170
      GO TO 37                                                          00001190
C                                        CLOSED APEX, .GT. 2ND HARMONIC 00001195
   29 DO 30 KN = 1,5                                                    00001200
      DO 30 JJ = 1,5                                                    00001210
      OMG(KN,JJ) = 0.0                                                  00001230
      ALM(KN,JJ) = 0.0                                                  00001240
      IF (KN .EQ. JJ) ALM(KN,JJ) = 1.0                                  00001250
   30 LLI(KN) = 0.0                                                     00001260
      GO TO 37                                                          00001270
C                                      1ST FOURIER COMPONENT, 1ST STA.  00001279
   31 DO 32 KN = 1,5                                                    00001280
      LLI(KN) = LLO(KN)                                                 00001285
      DO 32 JJ = 1,5                                                    00001290
      OMG(KN,JJ) = OMGO(KN,JJ)                                          00001300
   32 ALM(KN,JJ) = ALMO(KN,JJ)                                          00001310
      GO TO 37                                                          00001330
C                                                                       00001339
   33 IF (MM .NE. N) GO TO 37                                           00001340
      IF (J .EQ. 1) GO TO 34                                            00001350
      IF (BCIB .NE. 1.0) GO TO 34                                       00001360
      IF (J .GT. 2) GO TO 29                                            00001370
      GO TO 27                                                          00001380
   34 DO 35 KN = 1,5                                                    00001390
      LLI(KN) = LLLN(KN)                                                00001395
      DO 35 JJ = 1,5                                                    00001400
      OMG(KN,JJ) = OMGN(KN,JJ)                                          00001410
   35 ALM(KN,JJ) = ALMN(KN,JJ)                                          00001420
C                                                                       00001439
   37 DO 9998  K = 1,KK                                                 00001440
      IF (II .NE. 1) GO TO 85                                           00001450
      IF (IFLG .NE. 1) GO TO 98                                         00001460
C                                                                       00001470
```

```
C                   RECURSION FORMS         *            *            *         00001480
C                                                                               00001490
   38 JMK = J - K                                                               00001500
      KMJA = 1 + IABS(K - J)                                                    00001510
      KPJ = K + J - 1                                                           00001520
      TERM1 = 1.0                                                               00001530
      IF (JMK .EQ. 0) TERM1 = 0.0                                               00001540
      TERM2 = 1.0                                                               00001550
      IF (K .EQ. 1) TERM2 = 0.0                                                 00001560
      FCTR = 1. - TERM1 + TERM2                                                 00001570
      FCTR2 = 1. - 2. * TERM2                                                   00001580
      IF(K+J .GT. 10) FCTR2 = 0.                                                00001582
C                                                                               00001590
      K1 = N2 * I + KPJ                                                         00001600
      K2 = N2 * (I-1) + KPJ                                                     00001610
      K3 = N2 * (I+1) + KPJ                                                     00001620
      K4 = N2 * I + KMJA                                                        00001630
      K5 = N2 * (I-1) + KMJA                                                    00001640
      K6 = N2 * (I+1) + KMJA                                                    00001650
      K7 = N2 * (I-2) + KPJ                                                     00001660
      K8 = N2 * (I-2) + KMJA                                                    00001670
      K9 = N2 * (I-3) + KPJ                                                     00001680
      K10 = N2 * (I-3) + KMJA                                                   00001690
C                                                                               00001700
      IF (MM .NE. 1) GO TO 55                                                   00001710
C                                                                               00001720
C                   FORWARD DIFFERENCE FOR FIRST STATION.              *        00001730
      IF(J .NE. 1) GO TO 39                                                     00001732
      TTP(K) = (4. * SCNTSI(K1) - 3. * SCNTSI(K2) - SCNTSI(K3)) /DEL2           00001733
      MTP(K) = (4. * SCMTSI(K1) - 3. * SCMTSI(K2) - SCMTSI(K3)) /DEL2           00001734
      TFE(K)   =   SCNTSI(K2)                                                   00001735
      MFE(K)   =   SCMTSI(K2)                                                   00001736
C                                                                               00001740
   39 BP1KPJ = (4. * SCB1(K1) - 3. * SCB1(K2) - SCB1(K3)) /DEL2                 00001750
      DP1KPJ = (4. * SCD1(K1) - 3. * SCD1(K2) - SCD1(K3)) /DEL2                 00001770
      G13KPJ = (4. * SCG13(K1) - 3. * SCG13(K2) - SCG13(K3)) /DEL2              00001780
      GP1KPJ = (4. * SCG1(K1) - 3. * SCG1(K2) - SCG1(K3)) /DEL2                 00001800
C                                                                               00001810
      BP1KMJ = (4. * SCB1(K4) - 3. * SCB1(K5) - SCB1(K6)) /DEL2                 00001820
      DP1KMJ = (4. * SCD1(K4) - 3. * SCD1(K5) - SCD1(K6)) /DEL2                 00001840
      G13KMJ = (4. * SCG13(K4) - 3. * SCG13(K5) - SCG13(K6)) /DEL2              00001850
      GP1KMJ = (4. * SCG1(K4) - 3. * SCG1(K5) - SCG1(K6)) /DEL2                 00001870
C                                                                               00001880
```

```
C                 DERIVATIVE OF STIFFNESS RECURSIONS.          *              00001890
C                                                                             00001900
   40 BB1P      =  0.5 *  (BP1KPJ + FCTR * BP1KMJ)                            00001910
      DD1P   =     0.5 * (DP1KPJ + FCTR * DP1KMJ)                             00001920
      GG13P = 0.5 * (FCTR * G13KMJ + FCTR2 * G13KPJ)                          00001930
      GG1P = 0.5 * (FCTR * GP1KMJ + FCTR2 * GP1KPJ)                           00001940
C                                                                             00001950
C                 STIFFNESS RECURSION   *          *           *              00001960
C                                                                             00001970
   50 BB1KJ  = 0.5 * (SCB1(K2) + FCTR * SCB1(K5))                             00001980
      DD1KJ  = 0.5 * (SCD1(K2) + FCTR * SCD1(K5))                             00001990
      GG13KJ = 0.5 * (FCTR * SCG13(K5) + FCTR2 * SCG13(K2))                   00002000
      GG1KJ = 0.5 * (FCTR * SCG1(K5) + FCTR2 * SCG1(K2))                      00002010
      DCK3KJ = 0.5 * (DCK3(K2) + FCTR * DCK3(K5))                             00002016
      GO TO 150                                                               00002020
C                                                                             00002030
   55 IF (MM .EQ. N) GO TO 65                                                 00002040
      IF(J .NE. 1) GO TO 57                                                   00002042
      TTP(K) = (SCNTSI(K1) - SCNTSI(K7)) /DEL2                                00002043
      MTP(K) = (SCMTSI(K1) - SCMTSI(K7)) /DEL2                                00002044
      TFE(K)  =  SCNTSI(K2)                                                   00002045
      MFE(K)  =  SCMTSI(K2)                                                   00002046
   57 BP1KPJ = (SCB1(K1) - SCB1(K7)) /DEL2                                    00002050
      DP1KPJ = (SCD1(K1) - SCD1(K7)) /DEL2                                    00002060
      G13KPJ = (SCG13(K1) - SCG13(K7)) /DEL2                                  00002070
      GP1KPJ = (SCG1(K1) - SCG1(K7)) /DEL2                                    00002080
C                                                                             00002090
C                                                                             00002100
   60 BP1KMJ = (SCB1(K4) - SCB1(K8)) /DEL2                                    00002110
      DP1KMJ = (SCD1(K4) - SCD1(K8)) /DEL2                                    00002120
      G13KMJ = (SCG13(K4) - SCG13(K8)) /DEL2                                  00002130
      GP1KMJ = (SCG1(K4) - SCG1(K8)) /DEL2                                    00002140
      GO TO 40                                                                00002150
C                                                                             00002160
C                 BACKWARD DIFFERENCE FOR LAST STATION.        *              00002170
   65 IF(J .NE. 1) GO TO 70                                                   00002172
      TTP(K) = (SCNTSI(K9) + 3. * SCNTSI(K2) - 4. * SCNTSI(K7)) /DEL2         00002173
      MTP(K) = (SCMTSI(K9) + 3. * SCMTSI(K2) - 4. * SCMTSI(K7)) /DEL2         00002174
      TFE(K)  =  SCNTSI(K2)                                                   00002175
      MFE(K)  =  SCMTSI(K2)                                                   00002176
C                                                                             00002180
   70 BP1KPJ = (SCB1(K9) + 3. * SCB1(K2) - 4. * SCB1(K7)) /DEL2               00002190
      DP1KPJ = (SCD1(K9) + 3. * SCD1(K2) - 4. * SCD1(K7)) /DEL2               00002200
```

```
      G13KPJ = (SCG13(K9) + 3. * SCG13(K2) - 4. * SCG13(K7)) /DEL2      00002210
      GP1KPJ = (SCG1(K9) + 3. * SCG1(K2) - 4. * SCG1(K7)) /DEL2         00002220
C                                                                       00002230
      BP1KMJ = (SCB1(K10) + 3. * SCB1(K5) - 4. * SCB1(K8)) /DEL2        00002240
      DP1KMJ = (SCD1(K10) + 3. * SCD1(K5) - 4. * SCD1(K8)) /DEL2        00002250
      G13KMJ = (SCG13(K10) + 3. * SCG13(K5) - 4.*SCG13(K8)) /DEL2       00002260
      GP1KMJ = (SCG1(K10) + 3. * SCG1(K5) - 4. * SCG1(K8)) /DEL2        00002270
      GO TO 40                                                          00002280
C                                                                       00002290
C                                                                       00002300
   85 IF (LN .EQ. N) GO TO 38                                           00002310
      IF (I .NE. 3) GO TO 93                                            00002320
C                                                AT ARBITRARY STATION 3 00002330
C                 SAVE COEFF. OF LAST TWO STAS. OF THIS BLOCK.  TO BE   00002340
C                 USED TO COMPUTE DERIVATIVES ON NEXT BLOCK.  *         00002350
C                                                                       00002360
      KK2 = 2 * KK                                                      00002370
      K11 = N2 * (LLN-2)                                                00002380
      K12 = N2 * (LLN-1)                                                00002390
      DO 90 IK = 1, KK2                                                 00002400
      K13 = K11 + IK                                                    00002410
      K14 = K12 + IK                                                    00002420
      P1ENT(IK) = SCNTSI(K13)                                           00002423
      P2ENT(IK) = SCNTSI(K14)                                           00002426
      P1SCB1(IK) = SCB1(K13)                                            00002430
      P2SCB1(IK) = SCB1(K14)                                            00002440
      P1SCD1(IK) = SCD1(K13)                                            00002450
      P2SCD1(IK) = SCD1(K14)                                            00002460
      P1SG13(IK) = SCG13(K13)                                           00002470
      P2SG13(IK) = SCG13(K14)                                           00002480
      P1SCG1(IK) = SCG1(K13)                                            00002490
      P2DCK3(IK) = DCK3(K14)                                            00002496
      P2SCG1(IK) = SCG1(K14)                                            00002500
      P1EMT(IK) = SCMTSI(K13)                                           00002503
      P2EMT(IK) = SCMTSI(K14)                                           00002506
   90 CONTINUE                                                          00002510
C                                              IS COEFF BLOCK COMPLETED 00002519
   93 IF (I .EQ. LLN) GO TO 10                                          00002520
C                                                          NO           00002529
      GO TO 38                                                          00002530
C                                                                       00002540
C                                                                       00002550
   98 JMK  = J - K                                                      00002560
```

```
      KMJA = 1 + IABS(K - J)                                            00002570
      KPJ = K + J - 1                                                   00002580
      TERM1 = 1.0                                                       00002590
      IF (JMK .EQ. 0) TERM1 = 0.0                                       00002600
      TERM2 = 1.0                                                       00002610
      IF (K .EQ. 1) TERM2 = 0.0                                         00002620
      FCTR = 1. - TERM1 + TERM2                                         00002630
      FCTR2 = 1. - 2. * TERM2                                           00002640
      IF(K+J .GT. 10) FCTR2 = 0.                                        00002645
C                                                                       00002650
      K1 = N2 * I + KPJ                                                 00002660
      K2 = N2 * (I-1) + KPJ                                             00002670
      K4 = N2 * I + KMJA                                                00002680
      K5 = N2 * (I-1) + KMJA                                            00002690
C                                                                       00002700
C          IRTE .NE. 1  - FIRST STATION IN A SECTION (NOT REGION).      00002701
C          IRTE .EQ. 1  - LAST STATION IN PREVIOUS SECTION.             00002702
C                                                                       00002703
  100 IF (IRTE .NE. 1) GO TO 110                                        00002710
C                                                                       00002719
C                  LAST STATION - PREVIOUS BLOCK                        00002720
      IF (K .NE. 1 .OR. J .NE. 1) GO TO 102                             00002730
      MM = MM - 1                                                       00002740
      MMN = MMN - 1                                                     00002750
  102 IF(J .NE. 1) GO TO 103                                            00002752
      TTP(K) = (SCNTSI(K2) - P1ENT(KPJ)) /DEL2                          00002753
      MTP(K) = (SCMTSI(K2) - P1EMT(KPJ)) /DEL2                          00002754
      TFE(K)  =  P2ENT(KPJ)                                             00002755
      MFE(K)  =  P2EMT(KPJ)                                             00002756
  103 BP1KPJ = (SCB1(K2) - P1SCB1(KPJ)) /DEL2                           00002760
      DP1KPJ = (SCD1(K2) - P1SCD1(KPJ)) /DEL2                           00002770
      G13KPJ = (SCG13(K2) - P1SG13(KPJ)) /DEL2                          00002780
      GP1KPJ = (SCG1(K2) - P1SCG1(KPJ)) /DEL2                           00002790
C                                                                       00002800
  105 BP1KMJ = (SCB1(K5) - P2SCB1(KMJA)) /DEL2                          00002810
      DP1KMJ = (SCD1(K5) - P2SCD1(KMJA)) /DEL2                          00002820
      G13KMJ = (SCG13(K5) - P2SG13(KMJA)) /DEL2                         00002830
      GP1KMJ = (SCG1(K5) - P2SCG1(KMJA)) /DEL2                          00002840
      GO TO 120                                                         00002850
C                                                                       00002860
C                  FIRST STATION - NOT FIRST BLOCK                      00002900
  110 IF (K .NE. 1 .OR. J .NE. 1) GO TO 111                             00002910
      MM = MM + 1                                                       00002920
```

```
      MMN = MMN + 1                                                     00002930
  111 IF(J .NE. 1) GO TO 112                                            00002932
      TTP(K) = (SCNTSI(K1) - P2ENT(KPJ)) /DEL2                          00002933
      MTP(K) = (SCMTSI(K1) - P2EMT(KPJ)) /DEL2                          00002934
      TFE(K)  =  SCNTSI(K2)                                             00002935
      MFE(K)  =  SCNTSI(K2)                                             00002936
  112 BP1KPJ = (SCB1(K1) - P2SCB1(KPJ)) /DEL2                           00002940
      DP1KPJ = (SCD1(K1) - P2SCD1(KPJ)) /DEL2                           00002950
      G13KPJ = (SCG13(K1) - P2SG13(KPJ)) /DEL2                          00002960
      GP1KPJ = (SCG1(K1) - P2SCG1(KPJ)) /DEL2                           00002970
C                                                                       00002980
      BP1KMJ = (SCB1(K4) - P2SCB1(KMJA)) /DEL2                          00002990
      DP1KMJ = (SCD1(K4) - P2SCD1(KMJA)) /DEL2                          00003000
      G13KMJ = (SCG13(K4) - P2SG13(KMJA)) /DEL2                         00003010
      GP1KMJ = (SCG1(K4) - P2SCG1(KMJA)) /DEL2                          00003020
C                                                                       00003030
  120 BB1P    =  0.5   * (BP1KPJ +  FCTR *  BP1KMJ)                     00003040
      DD1P      = 0.5 * (DP1KPJ + FCTR * DP1KMJ)                        00003050
      GG13P = 0.5 * (FCTR * G13KMJ + FCTR2 * G13KPJ)                    00003060
      GG1P = 0.5 * (FCTR * GP1KMJ + FCTR2 * GP1KPJ)                     00003070
C                                                                       00003080
  125 IF (IRTF .NE. 1) GO TO 135                                        00003090
      TERM11 = P2SCB1(KPJ)                                              00003100
      TERM21 = P2SCD1(KPJ)                                              00003120
  130 BB1KJ     = 0.5 * (TERM11 + FCTR * P2SCB1(KMJA))                  00003130
      DD1KJ     = 0.5 * (TERM21 + FCTR * P2SCD1(KMJA))                  00003140
      GG13KJ = 0.5 * (FCTR * P2SG13(KMJA) + FCTR2 * P2SG13(KPJ))        00003150
      GG1KJ = 0.5 * (FCTR * P2SCG1(KMJA) + FCTR2 * P2SCG1(KPJ))         00003160
      DCK3KJ = 0.5 * (P2DCK3(KPJ) + FCTR * P2DCK3(KMJA))                00003166
      GO TO 150                                                         00003170
C                                                                       00003180
  135 BB1KJ  = 0.5 * (SCB1(K2) + FCTR * SCB1(K5))                       00003190
      DD1KJ  = 0.5 * (SCD1(K2) + FCTR * SCD1(K5))                       00003200
      GG13KJ = 0.5 * (FCTR * SCG13(K5) + FCTR2 * SCG13(K2))             00003210
      GG1KJ = 0.5 * (FCTR * SCG1(K5) + FCTR2 * SCG1(K2))                00003220
      DCK3KJ = 0.5 * (DCK3(K2) + FCTR * DCK3(K5))                       00003226
C                                                                       00003230
  150 BB2KJ   =    BB1KJ                                                00003250
      BB3KJ  =  POI  *  BB1KJ                                           00003260
      SS2  =  (1. - POI) / 2.                                           00003270
      GG2KJ = SS2 * BB1KJ                                               00003280
      GG3KJ  =  GG1KJ                                                   00003290
      BB3P   =   POI  *  BB1P                                           00003300
```

```
      GG3P  = GG1P
      GG2P  = SS2 * BB1P
      DD2KJ    =   DD1KJ
      DD3KJ  =  POI    *  DD1KJ
      DD3P  =  POI * DD1P
      DCK1KJ  =  0.
      DCK2KJ  =  0.
      TFETK  =  TFE(K)
      TTHTK  =  TFE(K)
      MFETK  =  MFE(K)
      MTHTK  =  MFE(K)
      TFETP  =  TTP(K)
      MFETP  =  MTP(K)
      IF(MMN .EQ. 0) GO TO 153
      PFEK  = PFE(K,MMN)
      PTHK = PTH(K,MMN)
      PNK = PN(K,MMN)
      GO  TO  154
C
  153 PFEK  =  PFE50(K)
      PTHK  =  PTH50(K)
      PNK   =  PN50(K)
C
C            P AND X FORMULATION                                  **
C
C
  154 WTH = WTHX(MM)
      WFE = WFEX(MM)
      GAM = GAMA(MM)
      RHO = RHOX(MM)
      WFEP = WFEPX(MM)
      LAM  =  HO /AO
      LAM2  =  LAM * LAM
      LAMO2  =  LAM /2.
      LAM2O2  =  LAM * LAMO2
      LAM2O4  =  LAMO2 * LAMO2
      LAM2O8  =  LAM2O4 /2.
      GAM2  =  GAM **2
      WTMWF  =  WTH - WFE
      WTMWF2  =  WTMWF **2
      WFWT  =  WFE * WTH
C
      IF (IFLG .NF. 1) GO TO 235
```

```
      IF (I .NE. 1) GO TO 235                                            00003730
C                                                                        00003740
C                                        SET UP BOUNDARY MATRICES        00003749
  155 CALL RSLT (J,K,KK)                                                 00003750
      IF (IRSFG .GT. 1)  GO TO 9998                                      00003760
      IF (IRSFG .EQ. 1)  GO TO 20                                        00003770
      RETURN                                                             00003780
C                                                                        ^0003790
  235 IF (I .NE. LLN)  GO TO 237                                         00003800
      IF (LN .EQ. N) GO TO 155                                           00003810
C                                                                        00003818
C                                 SET UP MATRICES IN EQUILIBRIUM EQ.     00003819
  237 CALL FGHPF (J,K,KK,IRTE)                                           00003820
      IF (IFGFG .GT. 1) GO TO 9998                                       00003830
      IF (IFGFG .EQ. 1) GO TO 20                                         00003840
      GO TO 23                                                           00003850
 9998 CONTINUE                                                           00003880
C                                                                        00003890
  340 FORMAT(1H-,14HENTERED PANDX. )                                     00003900
      RETURN                                                             00003910
      END                                                                00003920
```

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3.11g RSLT Subroutine (BNDRY)

```
$IBFTC BNDRY                                                            00000010
C                                                                       00000019
      SUBROUTINE RSLT (J,K,KK)                                          00000020
C                                                                       00000030
C        COMPUTES THE BOUNDARY MATRICES FOR 'P AND X' MATRICES.         00000040
C                                                                       00000050
      DIMENSION    R(50,50), AA (50,50), S(50,50), LT(50)               00000060
      DIMENSION  P(50,50), X(50), ZX(50)                                00000080
C                                                                       00000089
      COMMON  GDA(25), DEL, N, NNF, NIB,                                00000090
     1 BMTX(160)                                                        00000100
C                                                                       00000109
      COMMON /PXCMN/     AM, LLN, I, IFLG, LN, IRSFG, IFGFG,            00000110
     1 BB1KJ, BB2KJ, BB3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,   00000111
     2 GG13KJ, TFETK, TTHTK, MFETK, MTHTK, BB1P, BB3P, GG1P, GG2P,      00000112
     3 DD1P, DD3P, GG13P, TFETP, MFETP, OMG(5,5), AL(5,5), LLI(5),      00000113
     4 WTH, WFE, GAM, RHO, WFEP, LAM, LAM2, LAM02, LAM202, LAM204,      00000114
     5 LAM208, GAM2, WTMWF, WTMWF2, WFWT, PTHK, PNK, PFLK, P, X,        00000115
     6 DCK1KJ, DCK2KJ, DCK3KJ                                           00000116
C                                                                       00000179
      COMMON /BLOCK1/  EMM2(50,50)                                      00000180
      COMMON /BLOCK2/  EMM3(50)                                         00000190
C                                                                       00000199
      EQUIVALENCE (GDA( 1),   AO),            (GDA( 2),   HO),          00000200
     1            (GDA( 3),   LO),            (GDA( 4), SIGO),          00000210
     2            (GDA( 5),  POT),            (GDA( 6),  ENF),          00000220
     3            (GDA( 7), BCIT),            (GDA( 8), BCIB),          00000230
     4            (GDA( 9),PFLAG),                                      00000231
     5                                        (GDA(12),  THT),          00000232
     6            (GDA(18),PPRNT)                                       00000233
C                                                                       00000240
      REAL    LAM, LAM02, LAM202, LAM204, LAM208, LAM2, KZRO, KZRO2,    00000250
     1         TFETK, TTHTK, TFETP, LT, LLI                             00000260
C      R, S, LT  MATRICES IN BOUNDARY EQUATIONS  (44, 45) SID 65-1655   00000270
C                                                                       00000280
      KK5  =  5 * NNF                                                   00000290
      KZRO  =  0.                                                       00000295
      IF (K .NE. 1)  GO TO 164                                          00000300
      IF (J .NE. 1)  GO TO 164                                          00000310
C                                                                       00000320
C               ZERO ARRAYS FOR ALL MATRICES.    *        *             00000330
C                                                                       00000340
      DO 163 KN = 1,KK5                                                 00000350
```

```
      LI(KN) = 0.0
      DO 162 JJ = 1,KF[illegible]
      S(KN,JJ)  = 0.0
      R(KN,JJ)  = 0.0
  162 CONTINUE
  163 CONTINUE
C
  164 IF(RHO .EQ. 0.)  GO TO 165
      KORO = FLOAT(K-1) / RHO
  165 KORO2  =  KORO * KORO
      R(5*K-4,5*J-4)= BB1KJ * OMG(1,1)
      R(5*K-3,5*J-3)= GG1KJ /2. + LAM208 * [illegible] * GG13KJ
      R(5*K-3,5*J) =  LAM204 * W1MWF * GG13KJ
      R(5*K-2,5*J-2)= GG2KJ * OMG(3,3)
      R(5*K-1,5*J-1)=  DD1KJ
      R(5*K,5*J-3) =  ((GG13KJ * [illegible] /2.) * 0.5) * OMG(5,5)
      R(5*K,5*J)=  GG13KJ  *  0.5 * OMG(5,5)
      R(5*K-4,5*J-3)  =  R(5*K-3,5*J-3)  *  OMG(1,2)
      R(5*K-4,5*J)   =  R(5*K-3,5*J)  *  OMG(1,2)
      R(5*K,5*J-1)   =  R(5*K-1,5*J-1) * OMG(5,4)
C
      S(5*K-4,5*J-4)=  GA[illegible] * [illegible]3KJ
      S(5*K-4,5*J-3)=  KORO  *  BB3KJ
      S(5*K-4,5*J-2)=  WFE  *  BB1KJ  +  WFH  *  BB[illegible]
      S(5*K-3,5*J-4)=  LAM208  *  WIMWE2  *  GG13KJ  -  GG1KJ /2.
      S(5*K-3,[illegible]J-3) = GA[illegible] * S(5*K-2,[illegible]*J-4)
      S(5*K-3,[illegible]J)  =  -GA[illegible] * S(5*K-3,5*J)
      S([illegible],5*J-4)  =  KO[illegible] * S(5*[illegible],5*J-4)
      [illegible]  =  -KORO * S(5*K-[illegible],5 J)
      S(5*K-2,5*J-4)=  [illegible]  *  GG2KJ * OMG(3,[illegible])
      S([illegible]-2,[illegible] J-1)=  GG2KJ * OMG(3,3)
      S(5*K-1,5 J-1)=  GA[illegible]  *  [illegible]KJ
      [illegible]  =  [illegible]  *  [illegible]
      S(5*K,[illegible]J-3)  =  GG13KJ * [illegible]  /4.
      S(5*K,5*J-[illegible]) = GAM * S(5*K,5*J-4)
      S(5*K,5*J-4)  =  KORO * S(5*K,5*J-4)
      S(5*K,5*J-1)=  - KORO  *  GG13KJ   /2.
      S(5*K,5*J)=  - GAM  *  GG13KJ /2.
      R(5*K-[illegible],5*J-3)  =  R(5*K-[illegible],5*J-3)  * [illegible](2,2)
      R(5*K-3,5*J)  =  R(5*K-3,5*J)  * OMG(2,2)
      R(5*K-1,5*J-1)  =  R(5*K-1,5*J-1) * OMG(4,4)
C
      S(5*K-4,5*J-4) = S(5*K-4,5*J-4) * OMG(1,1) + S(5*K-3,5*J-4)  *
```

```
     1 OMG(1,2)
      S(5*K-4,5*J-3) = S(5*K-4,5*J-3) * OMG(1,1) + S(5*K-3,5*J-3) *
     1OMG(1,2)
      S(5*K-4,5*J-2) = S(5*K-4,5*J-2) * OMG(1,1)
      S(5*K-4,5*J-1) =  S(5*K-3,5*J-1) * OMG(1,2)
      S(5*K-4, 5*J)  =  S(5*K-3, 5*J) * OMG(1,2)
      S(5*K-3,5*J-3)=S(5*K-3,5*J-3) * OMG(2,2)
      S(5*K-3,5*J) = S(5*K-3,5*J) * OMG(2,2)
      S(5*K-3,5*J-4) = S(5*K-3,5*J-4) * OMG(2,2)
      S(5*K-3,5*J-1) = S(5*K-3,5*J-1) * OMG(2,2)
      S(5*K,5*J-4) = S(5*K,5*J-4) * OMG (5,5)
      S(5*K,5*J-3) = S(5*K,5*J-3) * OMG(5,5)
      S(5*K,5*J-1) = S(5*K,5*J-1) * OMG(5,5) + S(5*K-1,5*J-1)  *
     1 OMG(5,4)
      S(5*K-1,5*J-1) = S(5*K-1,5*J-1) * OMG(4,4)
      S(5*K,5*J)  = S(5*K,5*J) * OMG(5,5) + S(5*K-1,5*J) * OMG(5,4)
      S(5*K-1,5*J) = S(5*K-1,5*J) * OMG(4,4)
C
      LT(5*K-4)    =   TFETK   *  OMG(1,1) + LLI(1)
      LT(5*K-3)   =  LLI(2)
      LT(5*K-2) = LLI(3)
      LT(5*K-1)    =     TFETK    *   OMG(4,4) + LLI(4)
      LT(5*K)   = LLI(5)
C
      IF (K .NE. J) GO TO 166
      S(5*K-2,5*J-2) = ALM(3,3)
      S(5*K-4,5*J-4) = S(5*K-4,5*J-4) + ALM(1,1)
      S(5*K-3,5*J-3) = S(5*K-3,5*J-3) + ALM(2,2)
      S(5*K-3,5*J-4) = S(5*K-3,5*J-4) + ALM(2,1)
      S(5*K-1,5*J-1) = S(5*K-1,5*J-1) + ALM(4,4)
      S(5*K-1,5*J) = S(5*K-1,5*J) + ALM(4,5)
      S(5*K,5*J) = S(5*K,5*J) + ALM(5,5)
C
  166 IF (K .NE. KK) GO TO 167
      IF (J .EQ.KK)  GO TO 169
  167 IRSFG = 10
      RETURN
C
  169 IF (IFLG .GT. 1) GO  TO 305
      IF (I .GT. 1) GO TO 305
      A  =  FILE (3,1)
C
C                INITIAL BOUNDARY      *          *          *
```

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```
C
      DO 175 K = 1,KK5
      DO 175 J = 1,KK5
  175 R(K,J)  =   (2./DEL) * R(K,J)
C
C                    SAVE  BO    *          *          *
      WRITE ( 3)  R
      DO 176 K = 1,KK5
      DO 176 J = 1,KK5
  176 AAO(K,J) =   -.25 * R(K,J)
C
C                    SAVE  AO    *          *          *          *
      WRITE ( 3) AAO
      DO 177 K = 1,KK5
      DO 177 J = 1,KK5
  177 EMM2(K,J) = 3. * AAO(K,J)
      CALL MAD (KK5,KK5, S, EMM2, S )
C
C                    SAVE  CO    *          *          *          *
      WRITE ( 3) S
C
C                    SAVE  GO    *          *          *          *
      WRITE ( 3) LT
  190 END FILE  3
      IRSEG = 1
  200 IF(PFLAG .EQ. -1.E+10)  WRITE(6,310)
      RETURN
C
C                    TERMINAL BOUNDARY      *          *          *
C
  305 DO 306 K = 1,KK5
      DO 306 J = 1,KK5
  306 R(K,J) =   (3./(2.*DEL))  * R(K,J)
      CALL MAD (KK5,KK5,  S, R, AA   )
      DO 307 K = 1,KK5
      DO 307 J = 1,KK5
      R(K,J) =   R(K,J) /3.
  307 S(K,J) =   -4. * R(K,J)
C
C                    SAVE  CN, BN, AN, GN (IN THAT ORDER)
C                    TO BE USED FOR  Z(N)
      WRITE (10) R, S, AAO, LT
      BACKSPACE 10

      BACKSPACE 10
C
      IRSEG = 0
      GO  TO  200
  310 FORMAT (1H-,11HLEFT ENDRY. )
      END
```

3.11h FGHPE Subroutine (FGMTX)

```
$IBFTC FGMTX
C
      SUBROUTINE FGHPE (J,K,KK,IRTF)
C
      DIMENSION             S(50,5 ), F(5,5 ), G(5 ,5 ), H(5,50),
     1 PF(50), P(50,50), X(50)
C
      COMMON  GDAT(25), DEL, N, NNF, NTH,
     1 BMTX(160)
C
      COMMON /PXCMN/      MM, LIN, I, IF    LN, IRSFG, IFGFG,
     1 BB1KJ, BB2KJ, BB3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,
     2 GG13KJ, TFETK, TTHTK, MFETK, MTHTK, BB1P, BB3P, GG1P, GG2P,
     3 DD1P, DD3P, GG13P, TFETP, MFETP, OMG(5,5), ALM(5,5), LLI(5),
     4 WTH, WFE, GAM, RHO, WFEP, LAM, LAM2, LAM02, LAM202, LAM204,
     5 LAM208, GAM2, WTMWF, WTMWF2, WFAT, PIHK, PNK, FFFK, P, X,
     6 DCK1KJ, DCK2KJ, DCK3KJ
C
      COMMON /BLOCK1/  EMM2(50,50)
      COMMON /BLOCK2/  FMM3(50)

      EQUIVALENCE (GDA( 1),    A0),                (GDA( 2),    H0),
     1             (GDA( 3),    E0),                (GDA( 4), SIG0),
     2             (GDA( 5),   POI),                (GDA( 6),  FNF),
     3             (GDA( 7), BCIT),                 (GDA( 8), BCIB),
     4             (GDA( 9),PFLAG),
     5                                              (GDA(12),  THT),
     6             (GDA(18),FPRNT)
C
      REAL   LAM, LAM02, LAM202, LAM204, LAM208, LAM2, KORO, KORO2,
     1          MFETK, MTHTK, MFETP, LT(50), LLI
C
C      F, G, H, PE  MATRICES IN EQUILIBRIUM EQUATIONS (33) SID 65-1632
C
      KK5  =  5 * NNF
      IF (K .NE. 1)  GO TO 164
      IF (J .NE. 1)  GO TO 164
C              ZERO ARRAYS FOR ALL MATRICES.     *           *
      DO 163 KN = 1,KK5
      PE(KN)  = 0.0
      DO 162 JJ = 1,KK5
      F(KN,JJ)  =  0.0
      G(KN,JJ)  =  0.0
```

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```
      H(KN,JJ)  =  0.0
  162 CONTINUE
  163 CONTINUE
C
  164 KORO = FLOAT(K-1) /RHO
  168 KORO2 = KORO * KORO
C
C     F,G,H,PE   MATRICES IN EQUILIBRIUM EQUATIONS (33)   SID 65-1633
C
      F(5*K-4,5*J-4)=  BB1KJ
      F(5 K-3,5*J-3) =    GG1KJ /2. + LAM208 * WTMWF2 * GG13KJ
      F(5*K-3, 5*J)  =    LAM204 * WTMWF * GG13KJ
      F(5*K-2,5*J-2)=  GG2KJ
      F(5*K-1,5*J-1)=  LAM2  *  DD1KJ
      F(5*K,5*J)=  LAM202  *  GG13KJ
C
      G(5*K-4,5*J-4)=  BB1P  +  GAM  *  BB1KJ
      G(5*K-4,5*J-3)=  KORO  * ( BB3KJ  +  GG1KJ  /2.  -  LAM208  *
     1 WTMWF2 *  GG13KJ  )
      G(5*K-4,5*J-2)=  WFF  * ( BB1KJ  +  GG2KJ  ) + WTH  *  BB3KJ
      G(5*K-4, 5*J)  =  KORO  *( - LAM204 * WTMWF * GG13KJ)
      G(5*K-3,5*J-4) = - G(5*K-4,5*J-3)
      G(5*K-3,5*J-3) =  GG1P /2. + LAM208 * ( WTMWF2 * GG13P - GG13KJ
     1* ( WTMWF2  *  GAM  + 2. *  WFEP  *  WTMWF ) ) +  GG1KJ  * GAM /2.
      G(5*K-3,5*J-1) =  -KORO * ( LAM204 * WTMWF * GG13KJ )
      G(5*K-3,5*J)  =  LAM204 *(GG13P * WTMWF - GG13KJ * (2. * GAM
     1  * WTMWF + WFEP ) )
      G(5*K-2,5*J-4) = - G(5*K-4,5*J-2)
      G(5*K-2,5*J-2)=  GG2P  +  GAM  *  GG2KJ
      G(5*K-2,5*J-1)  =  GG2KJ
      G(5*K-1,5*J-3) = - G(5*K-3,5*J-1)
  180 G(5*K-1,5*J-2) =  G(5*K-2,5*J-1)
      G(5*K-1,5*J-1)= LAM2 * (  DD1P  +  GAM  *  DD1KJ  )
      G(5*K-1,5*J)=  KORO * ( LAM2  *  DD3KJ  +  LAM202  *  GG13KJ  )
      G(5*K,5*J-4) = - G(5*K-4,5*J)
      G(5*K, 5*J-3)  =  LAM204 *(GG13P * WTMWF + GG13KJ * (2. * GAM *
     1   WTMWF  - WFEP )  )
      G(5*K,5*J-1) = - G(5*K-1,5*J)
  183 G(5*K,5*J)= LAM202 * ( GG13P  +  GAM  * GG13KJ  )
C
      H(5*K-4,5*J-4)= GAM * BB3P  - WFWT  *  BB3KJ  - GAM2  *  BB2KJ -
     1  KORO2 *(GG1KJ /2. + LAM208 * WTMWF2 * GG13KJ) - WFF **2 * GG2KJ
     2  -  DCK1KJ
```

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```
      H(5*K-4,5*J-3)=  KORO * ( BB3P   -   GAM   *   BB2KJ   -   GAM /2. *     00000850
     1  GG1KJ - GAM * WTMWF2 * LAM208 * GG13KJ )                               00000851
      H(5*K-4,5*J-2)=  WFE *  BB1P  +  WTH * ( BB3P  -  GAM *  BB2KJ  ) 00000880
     1 +  BB1KJ  * (  WFEP  +  GAM  *  WFF  )                                  00000890
  189 H(5*K-4,5*J-1) =  WFE * GG2KJ + KORO2 *(LAM204 * WTMWF * GG13KJ)  00000900
      H(5*K-4, 5*J)  =  KORO * GAM * LAM204 * WTMWF * GG13KJ                   00000930
      H(5*K-3,5*J-4)= KORO * ( LAM208 * (  WTMWF2 * GG13P  - WTMWF  *         00000950
     1  GG13KJ  * ( 3. * GAM * WTMWF -  2. *  WFEP ) ) - GG1P /2. + GAM 00000951
     2  * ( -GG1KJ /2. - BB2KJ ) )                                             00000952
      H(5*K-3,5*J-3)  =  (WFWT - GAM2) /2. * GG1KJ - GAM /2. * GG1P          00000980
     1  - KORO2 * BB2KJ - WTH **2 * GG3KJ + LAM208 * ( GAM * WTMWF2 *         00000981
     2   GG13P - GG13KJ * ( WTMWF2 *(WFWT + 3.*GAM2) + 2. * WTMWF              00000982
     3   * GAM * WFEP ) ) - DCK2KJ                                             00000983
  190 H(5*K-3,5*J-2)=- KORO * ( WFF *  BB3KJ + WTH * (  BB2KJ  + GG3KJ))00001020
      H(5*K-3,5*J-1)= KORO * ( LAM204 * ( GAM * ( 2. * WTMWF  +  WFEP )*00001030
     1  GG13KJ  - WTMWF * GG13P ))                                             00001040
      H(5*K-3, 5*J) =  WTH * GG3KJ + LAM204 * WTMWF *                          00001060
     2 ( GG13KJ  * ( WFWT + 2. * GAM2 ) - GAM *  GG13P  ) + GAM * LAM20400001080
     3  *  WFEP  *  GG13KJ                                                     00001090
  193 H(5*K-2,5*J-4)=-  GG2KJ * ( WFFP  + GAM * WFF ) - WFF * ( GAM *         00001100
     1 BB3KJ  +  GG2P ) - WTH *  GAM  * BB2KJ                                  00001110
      H(5*K-2,5*J-3) = H(5*K-3,5*J-2)                                          00001120
      H(5*K-2,5*J-2)=- KORO2 *  GG3KJ - WFE **2  *  BB1KJ -  WTH * ( 2.*00001130
     1 WFE *  BB3KJ + WTH  *  BB2KJ  ) - DCK3KJ                                00001140
      H(5*K-2,5*J-1)= GG2P +  GAM *    GG2KJ                                   00001150
      H(5*K-2,5*J)= KORO *   GG3KJ                                             00001170
      H(5*K-1,5*J-4) = H(5*K-4,5*J-1)                                          00001190
      H(5*K-1,5*J-3) =  KORO * LAM204 * GAM * WTMWF * GG13KJ                   00001200
  195 H(5*K-1,5*J-1)= LAM2 * ( GAM * DD3P  - WFWT *  DD3KJ  - KORO2 /2. 00001250
     1 *  GG13KJ - GAM2 *  DD2KJ  ) -   GG2KJ                                  00001260
      H(5*K-1,5*J)= LAM2 * KORO * (  DD3P - GAM * ( GG13KJ  /2. +              00001270
     1  DD2KJ  )  )                                                            00001280
      H(5*K,5*J-4)= KORO *   LAM204 * ( WTMWF *  GG13P - WFEP *  GG13KJ)00001290
      H(5*K, 5*J-3) =  LAM204 * (GAM * WTMWF * GG13P - GG13KJ * (GAM *         00001310
     1   WFEP + WFWT * WTMWF ) ) + WTH * GG3KJ                                 00001311
      H(5*K,5*J-2) = H(5*K-2,5*J)                                              00001340
  198 H(5*K,5*J-1)=- KORO * ( LAM202 * ( GG13P + GAM *  GG13KJ ) + LAM2 00001350
     1 * GAM *  DD2KJ  )                                                       00001360
      H(5*K,5*J)= LAM202 * ( ( WFWT -  GAM2 ) *  GG13KJ - GAM * GG13P ) 00001370
     1 - KORO2 * LAM2 * DD2KJ  -  GG3KJ                                        00001380
C                                                                              00001389
      PE(5*K-4)  =  - PFEK + TFETP + GAM * ( TFETK - TTHTK  )                  00001390
      PE(5*K-3) =  - PTHK    -    TTHTK  *  KORO                               00001400
```

```
      PE(5*K-2)  =  - PNK  -  WFC * THETK  -  WIH * TTHIK               00001410
      PE(5*K-1)  =  LAM2  *  (MFETP  +  GAM * (MFETK - 2THIK) )         00001420
      PE(5*K)  =  - KORO * LAM2 * MTHTK                                 00001430
C                                                                       00001440
      IF (K .NE. KK) GO TO 203                                          00001450
      IF (J .EQ. KK)  GO TO 208                                         00001460
  203 IFGFG = 10                                                        00001470
      GO  TO  261                                                       00001480
C                                                                       00001490
C                                                                       00001500
C                 FORM MATRICES  A, B, C, F(PE)     *          *        00001510
C                                                                       00001520
  208 DO 210 K=1,KK5                                                    00001530
      DO 210 J = 1,KK5                                                  00001540
  210 F(K,J) =  (2./DEL) * F(K,J)                                       00001550
      CALL MAD (KK5,KK5, F, G, EMM2 )                                   00001560
      CALL MSU (KK5,KK5, F, G,  G )                                     00001570
      DO 212 K = 1,KK5                                                  00001580
      PE(K)  =  2. * DEL * PE(K)                                        00001590
      DO 212 J = 1,KK5                                                  00001600
      H(K,J) =  2. * DEL * H(K,J)                                       00001610
  212 F(K,J) = - 2. * F(K,J)                                            00001620
      CALL MAD (KK5,KK5, F,  H,  H )                                    00001630
      DO 214 K = 1,KK5                                                  00001640
      DO 214 J = 1,KK5                                                  00001650
  214 F(K,J) = FMM2(K,J)                                                00001660
C                                                                       00001670
C        COMPUTE P AND X                                **              00001680
      IF (MM .NE. 2) GO TO 240                                          00001690
C                                                                       00001700
      CALL INVNNM (G, 50, KK5, IERR )                                   00001710
C                                                                       00001720
      IF (IERR .LE. 0) GO TO 320                                        00001730
C                                                                       00001740
C                 WRITE ON TAPE  -  TO BE USED WHEN FORMING  Z(1)       00001750
C                 ORDER  -      A, B, C, G                              00001760
C                                                                       00001770
      WRITE ( 3) F, H, G, PE                                            00001780
      BACKSPACE  3                                                      00001790
      BACKSPACE  3                                                      00001800
C                                                                       00001810*
C                 STATION NO. 2  -  TOP BOUNDARY    *          *        00001820
C                                                                       00001830
```

*BACKSPACE 3 WHEN NOT USING ALTIØ

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```
C               READ MATRICES GENERATED IN 'RSLT'.           *        00001840
C                                                                     00001850
C                                                                     00001860
C               READ   G0   *       *       *       *                 00001870
C                                                                     00001880
      READ ( 3) LT                                                    00001890
      BACKSPACE 3                                                     00001900
      BACKSPACE 3                                                     00001910
C                                                                     00001920
C               READ   C0   *       *       *       *                 00001930
C                                                                     00001940
      READ ( 3) S                                                     00001950
      CALL MMY (KK5,KK5,KK5,  S,  G, EMM2 )                           00001960
      CALL MMY (KK5,KK5,KK5, EMM2,  F,  G )                           00001970
      BACKSPACE 3                                                     00001980
      BACKSPACE 3                                                     00001990
C                                                                     00002000
C               READ   A0   *       *       *       *                 00002010
C                                                                     00002020
      READ ( 3) S                                                     00002030
      CALL MSU (KK5, KK5,  S, G, F )                                  00002040
      CALL MMY (KK5,KK5,KK5, EMM2,  H,  G )                           00002050
      BACKSPACE 3                                                     00002060
      BACKSPACE 3                                                     00002070
C                                                                     00002080
C               READ   B0   *       *       *       *                 00002090
C                                                                     00002100
      READ ( 3) S                                                     00002110
      CALL MSU (KK5,KK5, S, G, S )                                    00002120
      CALL MMY (KK5,KK5,  1, EMM2, PF, EMM3 )                         00002130
      CALL MSU (KK5,  1, LT, EMM3, LT )                               00002140
      CALL INVNNM (S, 50, KK5,IERR )                                  00002150
      IF (IERR .LE. 0)  GO TO 320                                     00002160
C                                                                     00002170
      CALL MMY (KK5, KK5, KK5, S, F, P )                              00002180
      CALL MMY (KK5,KK5,  1, S, LT, X )                               00002190
      BACKSPACE  3                                                    00002200
      BACKSPACE  3                                                    00002210*
C                                                                     00002220
  225 WRITE (10) I, P, X                                              00002230
  230 IFGFG  =  1                                                     00002240
      GO  TO  261                                                     00002250
C                                                                     00002260
```

*BACKSPACE 3 WHEN NOT USING ALTI0

```
C
  240 CALL MMY (KK5,KK5,KK5, G, P, [illegible] )
      CALL  SU (KK5,KK5, H, [illegible]2, H )
      CALL INV[illegible] (H, 5, KK5, IERR )
      IF (IERR .LE. 0) GO TO 320
  248 CALL MMY (KK5, KK5, 1 , G, X, [illegible] )
      CALL MSU (KK5,  1, PE, EM[illegible]3, PF )
      CALL MMY (KK5,KK5,KK5, H, F, [illegible] )
      CALL MMY (KK5,KK5,  1, H, PE, X )
C
      WRITE (10) I, P, X
      IF (I .NE. 1) GO TO 250
      IF (IRTE .NE. 1) GO TO 250
      IRTE = 0
      IFGFG = 0
      IF (MM .EQ. N-2) GO TO 260
      RETURN
  250 IF (MM .NE. N-2) GO TO 230
      IFGFG = 1
C
  260 WRITE ( 4) P, X
      BACKSPACE  4
  261 IF(PFLAG .EQ. -1.E+10)  WRITE (6,262)
  262 FORMAT (1H-,11HLEFT EGMIX. )
      RETURN
  320 WRITE (6,325)  I
  325 FORMAT (1H-,9X,16HSINGULAR MATRIX.,9X,4HI = ,I4)
      CALL EXIT
      STOP
      END
```

3.11i ZMTRX Subroutine (SOLTN)

```
$IBFTC SOLTN                                                            00000010
C         SOLUTION MATRICES                                             00000020
C                                                                       00000029
      SUBROUTINE  ZMTRX                                                 00000030
C                                                                       00000040
C                                                                       00000050
      DIMENSION  PX(50,50),  XX(50), ZX(50), AAI1(50,50), BBI1(50,50),  00000080
     1 CCI1(50,50), GGI1(50), Z(50)                                     00000090
      DIMENSION ZX2(50),                BBO(50,50), GGO(50)             00000100
C                                                                       00000109
      EQUIVALENCE  (GDA( 9), PFLAG)                                     00000110
C                                                                       00000119
      COMMON /BLK1/  EMM2(50,50)                                        00000120
      COMMON /BLK2/  EMM3(50)                                           00000130
      COMMON  GDA(25), DEL, N, NNF, NIH,                                00000140
     1 BMTX(160)                                                        00000150
C                                                                       00000160
      A = FILE (3,2)                                                    00000170
C                                                                       00000180
      DO 15 I = 1,50                                                    00000190
   15 Z(I) = 0.0                                                        00000200
C                                                                       00000210
C                    READ MATRICES P AND X FOR STA. (N-2)               00000220
C                                                                       00000230
      READ ( 4) BBO, GGO                                                00000240
      END FILE 4                                                        00000250
C                                                                       00000260
      KK5  =   5 * NNF                                                  00000270
      DO 100 NN = 1,N                                                   00000280
      MN = N - NN + 1                                                   00000290
      IF (NN .NE. 1) GO TO 20                                           00000300
C                                                                       00000310
C                    READ MATRICES P AND X FOR STA. (N-1).              00000320
C                                                                       00000330
      READ (10) I, PX, XX                                               00000340
C                                                                       00000350
C                    READ MATRICES A, B, C, E(PE) GENERATED FOR STA. (N)00000360
C                                                                       00000370
      READ (10) AAI1, BBI1, CCI1, GGI1                                  00000380
      CALL MMMY(KK5,KK5,KK5, AAI1, BBO, EMM2 )                          00000390
      CALL MMSU(KK5, KK5, EMM2, BBI1, BBI1 )                            00000400
      CALL MMMY(KK5, KK5,  1, AAI1, GGO, EMM3 )                         00000410
      CALL MMSU(KK5,   1, GGI1, EMM3, GGI1 )                            00000420
```

```
      CALL MMMY(KK5, KK5,  1, BBI1, XX, EMM3 )                          00000430
      CALL MMAD(KK5,  1, GGI1, EMM3, GGI1 )                             00000440
      CALL MMMY(KK5, KK5, KK5, BBI1, PX, EMM2 )                         00000450
      CALL MMAD(KK5, KK5, CCI1, EMM2, CCI1 )                            00000460
      CALL INVMS  (CCI1, 50, KK5, IERR )                                00000470
      IF (IERR .LE. 0) GO TO 120                                        00000480
      CALL MMMY(KK5, KK5,  1, CCI1, GGI1, ZX )                          00000490
C                                                                       00000499
      WRITE ( 4) MN, ZX                                                 00000500
C                                                                       00000509
      WRITE (6, 130) MN,  (ZX(IX), IX=1,KK5)                            00000510
      GO TO 100                                                         00000520
C                                                                       00000530
   20 IF (NN .EQ. N) GO TO 40                                           00000540
      BACKSPACE 10                                                      00000550
      BACKSPACE 10                                                      00000560
      READ  (10) I, PX, XX                                              00000570
C                                                                       00000580
      CALL MMMY (KK5, KK5,  1, PX, ZX, Z )                              00000590
      CALL MMSU (KK5, 1, XX, Z, Z )                                     00000600
C                                                                       00000610
      IF (NN .NE. N-2) GO TO 30                                         00000620
      DO 25 K = 1,KK5                                                   00000630
   25 ZX2(K) = Z(K)                                                     00000640
   30 DO 35 K = 1,KK5                                                   00000650
   35 ZX(K) = Z(K)                                                      00000660
C                                                                       00000669
      WRITE ( 4) MN, ZX                                                 00000670
C                                                                       00000679
      WRITE (6, 140) MN,  (ZX(IX), IX=1,KK5)                            00000680
      GO TO 100                                                         00000690
C                                                                       00000700
C                                                                       00000710
C                 READ MATRICES A, B, C, E(PE) GENERATED FOR STA. (2)   00000720
C                                                                       00000730
   40 READ ( 3) AAI1, BBI1, CCI1, GGI1                                  00000740
      CALL MMMY(KK5,KK5,  1, BBI1, ZX, PX )                             00000750
      CALL MMMY(KK5,KK5,  1, AAI1, ZX2, ZX )                            00000760
      CALL MMSU(KK5,  1, GGI1, ZX, GGI1 )                               00000770
      CALL MMSU(KK5,  1, GGI1, PX, GGI1 )                               00000780
      CALL MMMY(KK5,KK5,  1, CCI1, GGI1, Z )                            00000790
C                                                                       00000800
      WRITE (6, 140) MN, (Z(IX), IY=1,KK5)                              00000810
```

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```
C                                                                       00000819
      WRITE ( 4) MN, Z                                                  00000820
  100 CONTINUF                                                          00000830
C                                                                       00000840
      IF(PFLAG .EQ. -1.E+10)  WRITE(6,109)                              00000842
  109 FORMAT (1H-, 10HLEFT SOLTN )                                      00000843
  110 RETURN                                                            00000850
C                                                                       00000859
  120 WRITE (6,125)                                                     00000860
      CALL EXIT                                                         00000870
      STOP                                                              00000880
  125 FORMAT (1H-,10X,45HERROR -  INVERSION OF SINGULAR MATRIX IN 'Z'. )00000890
C                                                                       00000900
  130 FORMAT (1H1,10X,24H'Z' MATRIX FOR STATION   , I4// (12X,1P5E17.7)) 00000910
  140 FORMAT (/// 10X,24H'Z' MATRIX FOR STATION   , I4// (12X,1P5E17.7)) 00000915
C                                                                       00000920
      END                                                               00000930
```

```
$IBFTC SUSM                                                                  00000010
C          SOLUTION SUMMATION    W/ STRESSES                  **             00000020
C                                                                            00000030
      SUBROUTINE SUMS                                                        00000040
C                                                                            00000041
C   NOMENCLATURF                                                             00000042
C     THT       HORIZONTAL ANGLFS (DEGREFS)  5 MAXIMUM                       00000043
C     FPRNT     FOURIER COMPONENT PRINT VALUES OF DEFLECTIONS AND            00000044
C               ROTATIONS   (3 POSSIBLE)                                     00000045
C                                                                            00000050
      DIMENSION  Z(50), THT( 6), FPRNT( 3)                                   00000060
      DIMENSION ULZ(100,5), VLZ(100,5), WLZ(100,5), PHSLZ(100,5),            00000070
     1          PHTLZ(100,5), UL(100,5), VL(100,5), WL(100,5),               00000080
     2          PHSL(100,5), PHTL(100,5), WFFX(100), WTHX(100),              00000090
     3          GAMA(100), RHOX(100), WFFPX(100)                             00000100
C                                                                            00000110
      DIMENSION B1(100,5), B2(100,5), B3(100,5), D1(100,5), D2(100,5), 00000150
     1          D3(100,5), G1(100,5), G2(100,5), G3(100,5), G13(100,5),00000151
     2          ENTSI(100,5), ENTTH(100,5), EMTSI(100,5), EMTTH(100,5) 00000152
C                                                                            00000160
      DIMENSION ENFE( 5), FNTH( 5), ENFT( 5), QFE( 5), EMFE( 5),             00000170
     1          EMTH( 5), EMFT( 5), QTH( 5)                                  00000180
C                                                                            00000190
      DIMENSION  SIGSI1(5), SIGTH1(5), TAUST1(5), TAUSG1(5),                 00000200
     1 TAUTG1(5), SIGSI2(5), SIGTH2(5), TAUST2(5), TAUSG2(5),                00000210
     2 TAUTG2(5)                                                             00000220
C                                                                            00000230
      DIMENSION  COFFC(3000)                                                 00000240
      DIMENSION  SCB1(200), SCB2(200), SCB3(200), SCG1(200), SCG2(200), 00000250
     1 SCG3( 200), SCD1(200), SCD2(200), SCD3(200), SCG13(200),              00000260
     2 SCNTSI(200), SCNTTH(200), SCMTSI(200), SCMTTH(200)                    00000270
C                                                                            00000390
      EQUIVALENCE (GDA( 1),   AO),             (GDA( 2),   HO),              00000400
     1            (GDA( 3),   EO),             (GDA( 4), SIGO),              00000410
     2            (GDA( 5),  POI),             (GDA( 6),  ENF),              00000420
     3            (GDA( 7), BCIT),             (GDA( 8), BCIB),              00000430
     4            (GDA( 9),PFLAG),                                           00000431
     5                                         (GDA(12),  THT),              00000432
     6            (GDA(18),FPRNT)                                            00000433
C                                                                            00000440
      EQUIVALFNCE (COEFC(   1),  SCB1),          (COEFC( 201),   SCB2), 00000450
     1            (COEFC( 401),  SCB3),          (COEFC( 601),   SCG1), 00000460
     2            (COEFC( 801),  SCG2),          (COEFC(1001),   SCG3), 00000470
```

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```
     3 (COEFC(1201),  SCD1), (COEFC(1401),  SCD2), (COEFC(1601),  SCD3),00000480
     4 (COEFC(1801), SCG13), (COEFC(2001),SCNTSI), (COEFC(2201),SCNTTH),00000490
     5 (COEFC(2401),SCMTSI), (COEFC(2601),SCMITH)                        00000500
C                                                                       00000510
      COMMON  GDA(25), DEL, N, NNF, NTH, BMTX(160)                      00000520
C                                                                       00000530
      REWIND   4                                                        00000540
C                                                                       00000600
      A = FILF (4,1)                                                    00000610
      SS1 = SIGO/FO                                                     00000620
      SS2 = SS1 * AO                                                    00000630
C                                                                       00000639
      DO 200 I = 1,N                                                    00000640
      IF(I .EQ. 1)  WRITE( 6,246)                                       00000645
      II = N - I + 1                                                    00000650
C                                                                       00000660
      READ ( 4) MN, Z                                                   00000670
C                                                                       00000680
      WRITE (6,290) II                                                  00000690
C                                                                       00000700
      DO 35 IT = 1,5                                                    00000710
      B1(I,IT)   =  0.0                                                 00000720
      D1(I,IT)   =  0.0                                                 00000722
      ENTSI(I,IT)   =  0.0                                              00000724
      EMTSI(I,IT)   =  0.0                                              00000726
      ULZ(I,IT) = 0.0                                                   00000730
      VLZ(I,IT) = 0.0                                                   00000740
      WLZ(I,IT) = 0.0                                                   00000750
      PHSLZ(I,IT) = 0.0                                                 00000760
   35 PHTLZ(I,IT) = 0.0                                                 00000770
C                                                                       00000780
      IT = 1                                                            00000790
   50 U = 0.0                                                           00000800
      V = 0.0                                                           00000810
      W = 0.0                                                           00000820
      PHS = 0.0                                                         00000830
      PHT = 0.0                                                         00000840
      IX = 1                                                            00000850
      THETA = THT(IT)                                                   00000860
C                                                                       00000870
      DO 150 NF = 1,NNF                                                 00000880
      ANF = NF - 1                                                      00000890
      NT = (NF - 1) * 5                                                 00000900
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
      NU = NT + 1                                                       00000910
      NV = NT + 2                                                       00000920
      NW = NU + 2                                                       00000930
      NFS = NV + 2                                                      00000940
      NFT = NW + 2                                                      00000950
      FCT = COSD (ANF * THETA)                                          00000960
      FCT2 = FCT * SS2                                                  00000970
      FCT1 = FCT * SS1                                                  00000980
      FCT3 = SIND (ANF * THETA)                                         00000990
      FCT4 = SS2 * FCT3                                                 00001000
      FCT5 = SS1 * FCT3                                                 00001010
C                                                                       00001020
      U = U + Z(NU) * FCT2                                              00001030
      V = V + Z(NV) * FCT4                                              00001040
      W = W + Z(NW) * FCT2                                              00001050
      PHS = PHS + Z(NFS) * FCT1                                         00001060
      PHT = PHT + Z(NFT) * FCT5                                         00001070
C                                                                       00001080
C                                 DERIVATIVES WITH RESPECT TO THETA 00001089
      ULZ(I,IT) = ULZ(I,IT) - Z(NU) * FCT4 * ANF                        00001090
      VLZ(I,IT) = VLZ(I,IT) + Z(NV) * FCT2 * ANF                        00001100
      WLZ(I,IT) = WLZ(I,IT) - Z(NW) * FCT4* ANF                         00001110
      PHSLZ(I,IT) = PHSLZ(I,IT ) - Z(NFS) * FCT5 * ANF                  00001120
      PHTLZ(I,IT) = PHTLZ(I,IT) + Z(NFT) * FCT1 * ANF                   00001130
C                                                                       00001140
      BNF = ANF + 1.                                                    00001150
      IF (BNF .NE. FPRNT(IX)) GO TO 150                                 00001160
C                                                                       00001170
      WRITE (6,300) THETA, ANF, U, V, W, PHS, PHT                       00001180
      IX = IX + 1                                                       00001190
  150 CONTINUE                                                          00001200
C                                                                       00001210
C                                            DISPLACEMENTS              00001229
      UL(I,IT) = U                                                      00001230
      VL(I,IT) = V                                                      00001240
      WL(I,IT) = W                                                      00001250
      PHSL(I,IT) = PHS                                                  00001260
      PHTL(I,IT) = PHT                                                  00001270
C                                                                       00001280
      IF (THT(IT+1) .LT. 0.0) GO TO 200                                 00001290
      IT = IT + 1                                                       00001300
      GO TO 50                                                          00001310
  200 CONTINUE                                                          00001320
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

```
C                                                                       00001330
      REWIND 4                                                          00001340
      IIT = IT                                                          00001350
      S1 = F0 * H0                                                      00001360
      S2 = S1 * H0 * H0                                                 00001370
      S3 = (1. - POI)/2.                                                00001380
      S4 = SIG0 * H0                                                    00001383
      S5 = A0 /(S4 * H0 **2)                                            00001386
      II = 0                                                            00001390
      NF2  =  2 * NNF                                                   00001400
C                                                                       00001410
  210 READ ( 9) LN, IN, COEFC                                           00001420
      LLN = LN - IN + 1                                                 00001430
      DO 240 I = 1,LLN                                                  00001440
      II = II + 1                                                       00001450
      K1 = NF2 * (I-1)                                                  00001460
C                                                                       00001470
      DO 230 IT = 1,IIT                                                 00001480
      THETA = THT(IT)                                                   00001490
      DO 225 NF = 1,NF2                                                 00001500
      ANF = NF - 1                                                      00001510
      K2 = K1 + NF                                                      00001520
      B1(II,IT) = B1(II,IT) + SCB1(K2) * COSD(ANF * THETA) * S1         00001530
      D1(II,IT) = D1(II,IT) + SCD1(K2) * COSD(ANF * THETA) * S2         00001540
      ENTSI(II,IT) = ENTSI(II,IT) + SCNTSI(K2) * COSD(ANF * THETA) * S4 00001543
      EMTSI(II,IT) = EMTSI(II,IT) + SCMTSI(K2) * COSD(ANF * THETA) * S5 00001546
  225 CONTINUE                                                          00001550
      B11 = B1(II,IT)                                                   00001560
      D11 = D1(II,IT)                                                   00001570
      B2(II,IT) = B11                                                   00001580
      B3(II,IT) = POI * B11                                             00001590
      D2(II,IT) = D11                                                   00001630
      D3(II,IT) = POI * D11                                             00001640
      G1(II,IT) = S3 * B11                                              00001650
      G2(II,IT) = S3 * B11                                              00001660
      G3(II,IT) = B11 * S3                                              00001670
      G13(II,IT) = S3 * D11                                             00001690
      ENTTH(II,IT) = ENTSI(II,IT)                                       00001710
      EMTTH(II,IT) = EMTSI(II,IT)                                       00001730
  230 CONTINUE                                                          00001740
  240 CONTINUE                                                          00001750
C                                                                       00001760
      IF (LN .EQ. N) GO TO 245                                          00001770
```

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR"

```
      GO TO 210                                                         00001750
C                                                                       00001790
  245 READ ( 4) WTHX, WFEX, GAMA, RHOX, WFEPX                           00001800
C                                                                       00001810
      K1  =  1                                                          00001820
      K2  =  2                                                          00001821
      DNM = -2. * DEL                                                   00001840
C                                                                       00001860
      DO 275 I = 1,N                                                    00001870
      IF(I .EQ. 1)  WRITE( 6,246)                                       00001872
  246 FORMAT( 1H1 )                                                     00001874
      L = N - I + 1                                                     00001880
      H = L                                                             00001890
      PEL  =  (H - 1.) * DEL                                            00001895
      WFF = WFEX(L)                                                     00001900
      WTH = WTHX(L)                                                     00001910
      GAM = GAMA(L)                                                     00001920
      RHO = RHOX(L)                                                     00001930
      DRHO =  0.                                                        00001940
      IF(RHO .NE. 0.)  DRHO = 1. /RHO                                   00001941
      DAO  =  1./AO                                                     00001950
C                                                                       00001959
      DO 265 IT = 1,IIT                                                 00001960
      THETA = THT(IT)                                                   00001970
      ZTA  =  THETA * .017453293                                        00001972
C                                    DERIVATIVES WITH RESPECT TO PSI    00001979
      IF (I .NE. 1) GO  TO 250                                          00001980
C                                                 LAST STATION          00001989
      ULP = (4. * UL(I+1,IT) - 3. * UL(I,IT) - UL(I+2,IT) )/ DNM        00001990
      VLP = (4. * VL(I+1,IT) - 3. * VL(I,IT) - VL(I+2,IT) )/ DNM        00002000
      WLP = (4. * WL(I+1,IT) - 3. * WL(I,IT) - WL(I+2,IT) )/ DNM        00002010
      PHSLP = (4. * PHSL(I+1,IT) - 3. * PHSL(I,IT) - PHSL(I+2,IT) )/DNM 00002020
      PHTLP = (4. * PHTL(I+1,IT) - 3. * PHTL(I,IT) - PHTL(I+2,IT) )/DNM 00002030
      GO TO 260                                                         00002040
  250 IF (I .EQ. N) GO TO 255                                           00002050
C                                  (NOTE - 'I' IS COUNTING BACKWARDS)   00002059
      ULP = (UL(I+1,IT) - UL(I-1,IT) ) /DNM                             00002060
      VLP = (VL(I+1,IT) - VL(I-1,IT) ) /DNM                             00002070
      WLP = (WL(I+1,IT) - WL(I-1,IT) ) /DNM                             00002080
      PHSLP = (PHSL(I+1,IT) - PHSL(I-1,IT) ) /DNM                       00002090
      PHTLP = (PHTL(I+1,IT) - PHTL(I-1,IT) ) /DNM                       00002100
      GO TO 260                                                         00002110
C                                                 FIRST STATION         00002119
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

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  255 ULP = (UL(I-2,IT) + 3. * UL(I,IT) - 4. * UL(I-1,IT) ) /DNM          00002120
      VLP = (VL(I-2,IT) + 3. * VL(I,IT) - 4. * VL(I-1,IT) ) /DNM          00002130
      WLP = (WL(I-2,IT) + 3. * WL(I,IT) - 4. * WL(I-1,IT) ) /DNM          00002140
      PHSLP = (PHSL(I-2,IT) + 3. * PHSL(I,IT) - 4. * PHSL(I-1,IT) )/DNM 00002150
      PHTLP = (PHTL(I-2,IT) + 3. * PHTL(I,IT) - 4. * PHTL(I-1,IT) )/DNM 00002160
C                                                                       00002170
C               COMPUTATION OF STRAINS ** (STR 139, PG.17) **           00002180
C                                                                       00002190
  260 ESI = DAO * (ULP + WFF * WL(I,IT))                                00002200
      ETH = DAO * (DRHO * VLZ(I,IT) + GAM * UL(I,IT) + WTH * WL(I,IT))  00002210
      ESTH = DAO/2. * (DRHO * ULZ(I,IT) + VLP - GAM * VL(I,IT) )        00002220
      GSI = PHSL(I,IT) - DAO * (WFF * UL(I,IT) - WLP )                  00002230
      GTH = PHTL(I,IT) - DAO * (WTH * VL(I,IT) - DRHO * WLZ(I,IT) )     00002240
      EKSI = DAO * PHSLP                                                00002250
      EKTH = DAO * (DRHO * PHTLZ(I,IT) + GAM * PHSL(I,IT) )             00002260
      EKSTH = DAO/2. * (DRHO * PHSLZ(I,IT) + PHTLP - GAM * PHTL(I,IT) + 00002270
     1 DAO/2.* (WFE-WTH)*(DRHO* ULZ(I,IT) - VLP-GAM*VL(I,IT)))          00002271
      IF(PFLAG .EQ. -10.)  WRITE(6,261) I, THETA, ESI, ETH, ESTH, GSI,  00002280
     1                                  GTH, EKSI, EKTH, EKSTH          00002281
  261 FORMAT(/// 10X, 34HCHECKPRINT OF STRAINS AT STATION  ,I4,  5X,    00002285
     1  7HTHETA   ,1PE12.4// 8F13.4 )                                   00002286
C                                                                       00002290
C               COMPUTATION OF INTERNAL FORCES ** (STR 139, PG.12) **   00002300
C                                                                       00002310
      ENFE(IT)   =   B1(L,IT) * ESI + B3(L,IT) * ETH - ENTSI(L,IT)      00002320
      ENTH(IT)   =   B3(L,IT) * ESI + B2(L,IT) * ETH - ENTTH(L,IT)      00002350
      ENFT(IT)   =   G1(L,IT) * ESTH                                    00002360
      QFE(IT)    = G2(L,IT) * GSI                                       00002370
      EMFE(IT)   =   D1(L,IT) * EKSI + D3(L,IT) * EKTH - EMTSI(L,IT)    00002380
      EMTH(IT)   =   D3(L,IT) * EKSI + D2(L,IT) * EKTH - EMTTH(L,IT)    00002400
      EMFT(IT)   =   G13(L,IT) * EKSTH                                  00002420
      QTH(IT)    = G3(L,IT) * GTH                                       00002430
C                                                                       00002440
C               COMPUTATION OF STRESSES ** (STR 139, PG.11) **          00002450
C                                                                       00002460
C                                                   INNER SURFACE       00002469
      OPE    =  EI1 (PEL,ZTA)                                           00002470
      IF (OPE .EQ. 0.) GO TO 265                                        00002471
      OPD    =  DN1 (PEL,ZTA)                                           00002472
      OPA    =  ALF1(PEL,ZTA)                                           00002474
      OPTT   =  TMP1(PEL,ZTA)                                           00002476
      POI1   =  POIS1 (PEL, ZTA)                                        00002478
      FTR = OPE /(1.-POI1*POI1)                                         00002510
```

```
      TERM = (OPA + POI1 * OPA) * OPTT                                  00002520
      TER = OPE/(2.*(1.+POI1) )                                         00002530
C                                                                       00002539
  262 SIGSI1(IT) = FTR * (ESI + POI1*ETH + OPD*(EKSI+POI1*EKTH) - TERM) 00002540
      SIGTH1(IT) = FTR * (ETH + POI1*ESI + OPD*(EKTH+POI1*EKSI) - TERM) 00002550
      TAUST1(IT) = TER * (ESTH + OPD * EKSTH)                           00002560
      TAUSG1(IT) = TER * GSI                                            00002570
      TAUTG1(IT) = TER * GTH                                            00002580
C                                                   SELECTED SURFACE    00002589
      OPD   =  DN2 (PEL,ZTA)                                            00002590
      OPE   =  EI2 (PEL,ZTA)                                            00002592
      OPA   =  ALF2(PEL,ZTA)                                            00002594
      OPTT  =  TMP2(PEL,ZTA)                                            00002596
      POI2  =  POIS2 (PEL, ZTA)                                         00002598
      FTR = OPE/(1.-POI2*POI2)                                          00002630
      TERM = (OPA + POI2 * OPA) * OPTT                                  00002640
      TER = OPE/(2.*(1.+POI2) )                                         00002650
C                                                                       00002659
  264 SIGSI2(IT) = FTR * (ESI + POI2*ETH + OPD*(EKSI+POI2*EKTH) - TERM) 00002660
      SIGTH2(IT) = FTR * (ETH + POI2*ESI + OPD*(EKTH+POI2*EKSI) - TERM) 00002670
      TAUST2(IT) = TER * (ESTH + OPD * EKSTH)                           00002680
      TAUSG2(IT) = TER * GSI                                            00002690
      TAUTG2(IT) = TER * GTH                                            00002700
  265 CONTINUE                                                          00002710
C                                                                       00002720
      WRITE (6,268) L, (ENFE(J), ENTH(J), ENFT(J), QFE(J), J = 1,IIT)   00002730
      WRITE (6,270)  (EMFE(J), EMTH(J), EMFT(J), QTH(J), J = 1,IIT)     00002740
      IF (OPE .EQ. 0.) GO TO 275                                        00002745
      WRITE (6,272) K1, (SIGSI1(J), SIGTH1(J), TAUST1(J), TAUSG1(J),    00002750
     1 TAUTG1(J), J = 1,IIT)                                            00002760
      WRITE (6,272) K2, (SIGSI2(J), SIGTH2(J), TAUST2(J), TAUSG2(J),    00002770
     1 TAUTG2(J), J = 1,IIT)                                            00002780
C                                                                       00002790
  268 FORMAT (1H-/11X,9HSTATION  ,I4// 19X, 5HN(XI),11X, 8HN(THETA), 7X,00002800
     1 11HN(XI,THETA),10X, 5HQ(XI) /(12X, 1P4E17.7) )                   00002810
C                                                                       00002820
  270 FORMAT (1H-,18X, 5HM(XI),11X, 8HM(THETA), 7X,11HM(XI,THETA), 8X,  00002830
     1 8HQ(THETA) / (12X, 1P4E17.7) )                                   00002840
C                                                                       00002849
  272 FORMAT (1H-/16X,18HSTRESSES FOR LAYER ,I4// 19X, 7HSIG(XI), 8X,   00002850
     1 10HSIG(THETA),6X,13HSIG(XI,THETA),5X,11HSIG(XI,ETA),5X,          00002860
     2 14HSIG(THETA,ETA) /(12X, 1P5E17.7) )                             00002870
C                                                                       00002880
```

```
  275 CONTINUE                                                          00002890
C                                                                       00002900
      IF(PFLAG .EQ. -1.E+10)  WRITE(6,280)                              00002902
  280 FORMAT (1H-, 9HLEFT SUMS )                                        00002904
      RETURN                                                            00002910
C                                                                       00002919
  290 FORMAT (/////10X, 9HSTATION   ,I4)                                00002920
  300 FORMAT (/// 10X, 9HTHETA   = ,F7.2//11X, 9HENF     = ,F5.1//21X,1HU,00002930
     1 16X,1HV,16X,1HW,12X, 7HPHI(XI), 9X,10HPHI(THETA) /(12X,1P5E17.7))00002940
C                                                                       00002950
      END                                                               00002960
```

3.12 PROGRAM LISTINGS FOR DYNAMICS VERSION

3.12a Executive Program

```
$IBFTC EXEC                                                              00000010
C         APOLLO WATER IMPACT ANALYSIS          **          **           00000020
C                                                                        00000030
C  REFERENCES ** AIAA JOURNAL, VOL. 1, NO. 8, AUG. 1963, PG.1833FF AND  00000040
C                VOL. 2, NO. 3, MARCH 1964, PG. 590FF                    00000050
C             ** SID 65-1633 REPORT, APOLLO WATER IMPACT ANALYSIS, NOV. 00000060
C                23, 1965, PG. 81FF                                      00000070
C                                                                        00000080
C     NOMENCLATURE                                                       00000090
C           A0        REFERENCE LENGTH (IN)                              00000100
C           H0        REFERENCE THICKNESS (IN)                           00000110
C           E0        REFERENCE YOUNG MODULUS (PSI)                      00000120
C           SIG0      REFERENCE STRESS (PSI)                             00000130
C           POI       POISSON RATIO                                      00000140
C           ENF       NO. OF FOURIER COMPONENTS                          00000150
C           BCIT      TOP BOUNDARY CONDITION FLAG                        00000180
C           BCIB      BOTTOM BOUNDARY CONDITION FLAG.                    00000181
C                 = 1.0     CLOSED APEX                                  00000182
C                 = 2.0     PINNED                                       00000183
C                 = 3.0     CLAMPED                                      00000184
C                 = 4.0     FREE                                         00000185
C                 = 5.0     ROLLER W                                     00000186
C                 = 6.0     ROLLER U                                     00000187
C                 = 10.0    SPECIAL BOUNDARY READ WITH GEOMETRY DATA     00000195
C           DELT      TIME INCREMENT                                     00000200
C           CEXT      NUMBER OF TIME CYCLES                              00000210
C           PFLAG     DATA PRINT INDICATOR                               00000220
C                 = 0.0     PRINTS GENERAL DATA AND BND. MATRICES        00000221
C                 = 1.0     PRINTS ABOVE INFORMATION AND INPUT DATA      00000222
C                           FOR A PARTICULAR GEOMETRY, AND THE PARA-     00000223
C                           METERS COMPUTED IN  GEOM                     00000224
C                 =-1.0     PRINTS ALL OF THE ABOVE INFORMATION AND      00000225
C                           STIFFNESS COEFFICIENTS, ELASTIC COEF.,       00000226
C                           THERMAL LOAD AND MOMENT AND PRESSURES        00000227
C           THT       CIRCUMFERENTIAL ANGLE THETA (DEGREES)  5 MAX       00000230
C           FPRNT     FOURIER COMPONENT PRINT VALUES. 3 PERMITTED        00000231
C                                                                        00000239
C                                                                        00000520
      DIMENSION   BCD(36), THT(6), FPRNT(3)                              00000525
C                                                                        00000529
      EQUIVALENCE (GDA( 1),   A0),              (GDA( 2),   H0),         00000530
     1            (GDA( 3),   E0),              (GDA( 4), SIG0),         00000531
     2            (GDA( 5),  POI),              (GDA( 6),  ENF),         00000532
```

```
     3             (GDA( 7), BCIT),                 (GDA( 8), BCIB),    00000533
     4             (GDA( 9),PFLAG),                 (GDA(10), CEXT),    00000534
     5             (GDA(11), DELT),                 (GDA(12),  THT),    00000535
     6             (GDA(18),FPRNT)                                      00000536
C                                                                       00000580
      COMMON  GDA(25), DEL, N, NNF, NTH,                                00000590
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                          00000591
C                                                                       00000608
C                                   READ AND PRINT 3 CARDS OF TITLE DATA 00000609
    5 READ (5,7)  BCD                                                   00000610
    7 FORMAT( 12A6 )                                                    00000611
      WRITE (6,8) BCD                                                   00000612
    8 FORMAT(1H1 /(18X, 12A6 //) )                                      00000613
C                                                                       00000619
      DO 10 L = 1,11                                                    00000620
      GDA(L+11)  =   -1.E+10                                            00000625
   10 GDA(L) = 0.0                                                      00000630
      KZTR   =   8                                                      00000640
      KZTW   =   11                                                     00000650
      KPTR   =   10                                                     00000660
      KPTW   =   12                                                     00000670
C                                         READ GENERAL DATA             00000680
      CALL DECRD (GDA)                                                  00000690
C                                                                       00000699
      IEXT   =   CEXT                                                   00000700
      IF(THT(1) .EQ. -1.E+10)  THT(1)   =  0.0                          00000702
      IF(FPRNT(1) .EQ. -1.E+10)  FPRNT(1)   =  ENF                      00000703
C                                                                       00000709
      DO    100     I = 1,IEXT                                          00000710
C                                          REWIND  ALL  TAPES           00000749
      REWIND  3                                                         00000750
      REWIND  4                                                         00000755
      REWIND  8                                                         00000760
      RFWIND  9                                                         00000770
      REWIND  10                                                        00000780
      REWIND  11                                                        00000790
      REWIND  12                                                        00000800
      REWIND  13                                                        00000810
C                                          SET  TIME  COUNTER           00000819
      TCTR   =   1                                                      00000820
C                                              DATA  LINK               00000849
      CALL DATLNK (I)                                                   00000850
C                                          FORM 'P' AND 'X' MATRICES    00000919
```

```
      CALL PANDX                                                        00000920
      END FILE 3                                                        00000930
      REWIND 3                                                          00000940
      IF (TCTR .EQ. 2.0)  BACKSPACE 10                                  00000950
C                                                     SOLUTIONS         00000960
      CALL ZMTRX                                                        00000970
C                                          SUMS AND INTERNAL LOADS      00000980
      CALL SUMS                                                         00000985
C                                                                       00000989
  100 CONTINUE                                                          00000990
C                                                                       00001000
      GO  TO  5                                                         00001010
      END                                                               00001030
```

3.12b DATLNK Subroutine (DLKDY)

```
$IBFTC DLKDY                                                            00000001
C     SUB-EXECUTIVE ROUTINE FOR GEOM, DATLYR AND DATLD TO PERMIT ONE    00000010
C        COPY OF CODIMA, ENTERP AND DINTRP IN THE DECK SET-UP           00000011
C                                                                       00000019
      SUBROUTINE DATLNK (I)                                             00000020
C                                                                       00000099
      COMMON  GDA(25), DEL, N, NNE, NTH,                                00000100
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                          00000101
C                                                                       00000189
      IF (I .NE. 1) GO TO 50                                            00000190
C                                 SET UP R, RHOX, GAMA, WTH, WFE, XSI   00000199
      CALL  GEOM                                                        00000200
C                                                                       00000218
C                                      SET UP MATERIAL PROPERTIES       00000219
      CALL  DATLYR                                                      00000220
      REWIND  9                                                         00000225
C                                                                       00000238
C                                      SET UP FOURIER LOAD COEFF.       00000239
   50 CALL  DATLD                                                       00000240
C                                                                       00000999
      RETURN                                                            00001000
C                                                                       00001009
      END                                                               00001010
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

3.12c GEOM Subroutine (GMYD)

```
$IBFTC GMYD                                                                00000010
C       * *  APOLLO WATER IMPACT STUDY    * *      GEOMETRY COMPUTATION ** 00000020
C                                                                          00000030
      SUBROUTINE GEOM                                                      00000040
C                                                                          00000050
C          GMI    -  GEOMETRY INDICATOR                 VIZ.    GIN        00000060
C                 =  1.0   - CONE - CYLINDER                     **        00000070
C                 =  2.0   - SPHERE - TOROID                     **        00000080
C                 =  3.0   - ARBITRARY FUNCTIONS                 **        00000090
C                 =  4.0   - GENERAL DISCRETE POINTS             **        00000100
C                  **                                            **        00000110
C         INPUTS -     GMI  = 1.0                                          00000120
C                   RA1    =    RADIUS AT STATION 1                        00000130
C                   AXL    =    AXIAL SURFACE LENGTH                       00000140
C                   ANX    =    ANGLE - GENERATOR AND AXIS OF REVOLUTION   00000150
C                  **                                            **        00000160
C                      GMI  = 2.0                                          00000170
C                 RC   =  RADIUS OF CURVATURE                              00000180
C                 ROFF   =  OFFSET DISTANCE TO CENTER OF CURVATURE         00000190
C                 PHIO   = INITIAL  OPENING ANGLE FROM VERTICAL AXIS       00000200
C                 PHIN   =  FINAL ANGLE                                    00000210
C                  **                                            **        00000220
C                    GMI    = 4.0  (- 4.0 DISCRETE ARCLENGTHS )            00000230
C                 EM     =  NUMBER OF RIPTS GIVEN                          00000240
C                 RIPT   =  DISCRETE RADII                                 00000250
C                 XIPT   =  DISCRETE XI'S (OR ARCLENGTHS)                  00000260
C                 RCURV  =  MERIDIONAL RADII OF CURVATURE                  00000270
C                 RCURZ  =  CIRCUMFERENTIAL RADII OF CURVATURE             00000280
C                  **                                            **        00000290
C                                                                          00000300
      DIMENSION WFW(16), WFP(4), STAP(4), STAW(16) , RRJ(12), RCRV(100),00000310
     1RCURZ(100), RCURV(100), RR(100), RIPT(100),XIPT(100), SARB(100),     00000320
     2SURF(100), XJ(11), RJ(11), DLR(10), R(100), XSI(100), WTHX(100),     00000330
     3WFEX(100), RHOX(100), GAMA(100), WFFPX(100), RCRZ(100), GMDA(442)    00000340
C                                                                          00000350
      DIMENSION BNDTX(17), BNDTB(17), THT(6), FPRNT(4)                     00000360
      DIMENSION  OMGO(5,5),  OMGN(5,5), ALMO(5,5), ALMN(5,5)               00000370
      DIMENSION  ALM1(5,5), OMG1(5,5)                                      00000380
      REAL  LLO(5),  LLLN(5)                                               00000390
C                                                                          00000400
      COMMON  GDA(25), DEL, N, NNF, NTH,                                   00000410
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                            00000420
C                                                                          00000430
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REPRODUCIBILITY OF THE ORIGINAL PAGE IS POC

```
      EQUIVALENCE  (BMTX(  1), OMG0),            (BMTX( 26), OMGN),     00000440
     1             (BMTX( 51), ALM0),            (BMTX( 76), ALMN),     00000450
     2             (BMTX(101), OMG1),            (BMTX(126), ALM1),     00000460
     3             (BMTX(151),  LL0),            (BMTX(156), LLLN)      00000470
C                                                                       00000479
      EQUIVALENCE (GDA( 1),    A0),            (GDA( 2),    H0),        00000480
     1             (GDA( 3),    F0),           (GDA( 4), SIG0),         00000490
     2             (GDA( 5),  POI),            (GDA( 6),  ENF),         00000500
     3             (GDA( 7), BCIT),            (GDA( 8), BCIB),         00000510
     4             (GDA( 9),PFLAG),            (GDA(10), CEXT),         00000511
     5             (GDA(11), DFLT),            (GDA(12),  THT),         00000512
     6             (GDA(18),FPRNT)                                      00000513
C                                                                       00000520
      EQUIVALENCE  (GMDA(  1),         GIN), (GMDA(  2),         FN),   00000530
     1             (GMDA(  3),       BLANK), (GMDA(  4),     RA1,RC),   00000540
     2             (GMDA(  5),    AXL,ROFF), (GMDA(  6),   ANX,PHI0),   00000550
     3             (GMDA(  7),        PHIN), (GMDA(  8),         FM),   00000560
     4             (GMDA(  9),        RIPT), (GMDA(109),       XIPT),   00000570
     5             (GMDA(209),       RCURV), (GMDA(309),      RCURZ),   00000580
     6             (GMDA(409),       BNDTX), (GMDA(426),      BNDTB)    00000590
C                                                                       00000600
      DO  2  I = 1,442                                                  00000610
    2 GMDA(I) = 0.0                                                     00000620
C                                                                       00000630
      CALL DECRD (GMDA)                                                 00000640
C                                                                       00000650
      DO  3 I = 1,160                                                   00000660
    3 BMTX(I) = 0.0                                                     00000670
C                                                                       00000680
      IF (BCIT .NE. 1.0) GO TO 5                                        00000690
C                                                     CLOSED APEX       00000700
      OMG0(3,3) = 1.0                                                   00000710
      OMG1 (1,1) = 1.0                                                  00000720
      OMG1 (1,2) = -1.0                                                 00000730
      OMG1 (5,4) = -1.0                                                 00000740
      OMG1 (5,5) = 1.0                                                  00000750
      ALM0(1,1) = 1.0                                                   00000760
      ALM0(2,2) = 1.0                                                   00000770
      ALM0(4,4) = 1.0                                                   00000780
      ALM0(5,5) = 1.0                                                   00000790
      ALM1 (2,1) = 1.0                                                  00000800
      ALM1 (2,2) = 1.0                                                  00000810
      ALM1(3,3) = 1.0                                                   00000820
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POO

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      ALM1(4,4) = 1.0                                                   00000830
      ALM1 (4,5) = 1.0                                                  00000840
      GO TO 21                                                          00000850
C                                                                       00000860
    5 IF (BCIT .NE. 10.) GO TO 10                                       00000870
C                                               SPECIAL BOUNDARY        00000880
      OMGO(1,1) = BNDTX( 1)                                             00000890
      OMGO(1,2) = BNDTX( 2)                                             00000900
      OMGO(2,2) = BNDTX( 3)                                             00000910
      OMGO(3,3) = BNDTX( 4)                                             00000920
      OMGO(4,4) = BNDTX( 5)                                             00000930
      OMGO (5,4) = BNDTX( 6)                                            00000940
      OMGO(5,5) = BNDTX( 7)                                             00000950
      ALMO(1,1) = BNDTX( 8)                                             00000960
      ALMO(2,2) = BNDTX( 9)                                             00000970
      ALMO(3,3) = BNDTX(10)                                             00000980
      ALMO(4,4) = BNDTX(11)                                             00000990
      ALMO(5,5) = BNDTX(12)                                             00001000
      DO  8 IJ = 1,5                                                    00001010
    8 LLO(IJ) = BNDTX(IJ+12)                                            00001020
      GO  TO  21                                                        00001030
C                                                                       00001040
   10 IBMX  =  BCIT                                                     00001050
      IO  =  1                                                          00001060
      IL  =  51                                                         00001070
C                                               CHOOSE BOUNDARY         00001080
   11 GO TO (21,12,13,14,15,16), IBMX                                   00001090
C                                               PINNED                  00001100
   12 BMTX(IO + 18)  =  1.                                              00001110
      BMTX(IO + 24)  =  1.                                              00001120
      BMTX(IL)  =  1.                                                   00001130
      BMTX(IL + 6)  =  1.                                               00001140
      BMTX(IL + 12)  =  1.                                              00001150
      GO  TO  20                                                        00001160
C                                               CLAMPED                 00001170
   13 BMTX(IL)  =  1.                                                   00001180
      BMTX(IL + 6)  =  1.                                               00001190
      BMTX(IL + 12)  =  1.                                              00001200
      BMTX(IL + 18)  =  1.                                              00001210
      BMTX(IL + 24)  =  1.                                              00001230
      GO  TO  20                                                        00001240
C                                                 FREE                  00001250
   14 BMTX(IO)  =  1.                                                   00001260
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
      BMTX(IO + 6)   =  1.                                          00001270
      BMTX(IO + 12)  =  1.                                          00001280
      BMTX(IO + 18)  =  1.                                          00001290
      BMTX(IO + 24)  =  1.                                          00001300
      GO  TO  20                                                    00001310
C                                                  ROLLER  W        00001320
   15 BMTX(IO + 12)  =  1.                                          00001330
      BMTX(IO + 18)  =  1.                                          00001340
      BMTX(IO + 24)  =  1.                                          00001350
      BMTX(IL)  =  1.                                               00001360
      BMTX(IL + 6)  =  1.                                           00001370
      GO  TO  20                                                    00001380
C                                                  ROLLER  U        00001390
   16 BMTX(IO)  =  1.                                               00001400
      BMTX(IO + 18)  =  1.                                          00001410
      BMTX(IO + 24)  =  1.                                          00001420
      BMTX(IL + 6)  =  1.                                           00001430
      BMTX(IL + 12)  =  1.                                          00001440
C                                                                   00001450
   20 IF(IO .NE. 1)  GO TO 28                                       00001460
C                                                                   00001470
   21 IF (RCIR .NE. 1.0) GO TO 23                                   00001480
C                                                  CLOSED APEX      00001490
      OMGN(3,3) = 1.0                                               00001500
      OMG1 (1,1) = 1.0                                              00001510
      OMG1 (1,2) = -1.0                                             00001520
      OMG1 (5,4) = -1.0                                             00001530
      OMG1 (5,5) = 1.0                                              00001540
      ALMN(1,1)  = 1.0                                              00001550
      ALMN(2,2)  = 1.0                                              00001560
      ALMN(4,4)  = 1.0                                              00001570
      ALMN(5,5)  = 1.0                                              00001580
      ALM1 (2,1) = 1.0                                              00001590
      ALM1 (2,2) = 1.0                                              00001600
      ALM1 (3,3) = 1.0                                              00001610
      ALM1(4,4) = 1.0                                               00001620
      ALM1 (4,5) = 1.0                                              00001630
      GO TO 28                                                      00001640
C                                                                   00001650
   23 IF (RCIR .NE. 10.) GO TO 25                                   00001660
C                                                  SPECIAL BOUNDARY 00001670
      OMGN(1,1) = BNDTB( 1)                                         00001680
      OMGN(1,2) = BNDTB( 2)                                         00001690
```

```
      OMGN(2,2) = BNDTB( 3)                                             00001700
      OMGN(3,3) = BNDTB( 4)                                             00001710
      OMGN(4,4) = BNDTB( 5)                                             00001720
      OMGN (5,4) = BNDTB( 6)                                            00001730
      OMGN(5,5) = BNDTB(7)                                              00001740
      ALMN(1,1) = BNDTB(8)                                              00001750
      ALMN(2,2) = BNDTB( 9)                                             00001760
      ALMN(3,3) = BNDTB(10)                                             00001770
      ALMN(4,4) = BNDTB(11)                                             00001780
      ALMN(5,5) = BNDTB(12)                                             00001790
      DO 24 IJ = 1,5                                                    00001800
   24 LLLN(IJ) = BNDTB(IJ+12)                                           00001810
      GO  TO  28                                                        00001820
C                                                                       00001830
   25 IBMX  =  BCIB                                                     00001840
      IO  =  26                                                         00001850
      IL  =  76                                                         00001860
      GO  TO  11                                                        00001870
C                                                                       00001880
   28 WRITE (6,1000) AO, HO, FO, SIGO, POI, ENF, BCIT, BCIB, PFLAG,     00001890
     1  CEXT, DFLT, THT, FPRNT,                                         00001891
     2  OMGO, ALMO, LLO, OMGN, ALMN, LLLN                               00001892
C                                                                       00001910
      N = EN                                                            00001920
      GMI = ABS(GIN)                                                    00001930
      NN = N - 1                                                        00001940
      IF (GMI - 2.0) 30, 35, 50                                         00001950
C                                                                       00001960
C                 CONE - CYLINDER                               **      00001971
C                                                                       00001980
   30 IF (PFLAG .NE. 0.0) WRITE(6,31)         N, RA1, AXL, ANX          00001990
C                                                                       00002000
   31 FORMAT (1H1,19X,33HGEOMETRY DATA FOR CONE - CYLINDER //35X,22HNUMB00002010
     1ER OF STATIONS -   ,I4//6X,7HRA1    =,1PE13.4,7X,7HAXL    =,E13.4,7X,00002020
     2 7HANX    =,E13.4)                                                00002030
C                                                                       00002040
      DEL =  AXL/(EN - 1.0)                                             00002050
      SINFI  = SIND(ANX)                                                00002060
      COSFI  = COSD(ANX)                                                00002070
      XSI(1) = 0.0                                                      00002080
      WTHX(1) = AO * COSFI/RA1                                          00002090
      WFEX(1) = 0.0                                                     00002100
      RHOX(1) = RA1/AO                                                  00002110
```

```
      R(1) = RA1
      DO 32 I = 2,N
      R(I)  = R(I-1) + DEL * SINFI
      XSI(I) = XSI(I-1) + DEL * COSFI
      WTHX(I) = A0 * COSFI/R(I)
      WFEX(I) = 0.0
   32 RHOX(I) = R(I)/A0
      GO TO 9
C
C                  SPHERE - TOROID                          **
C
   35 IF (PFLAG .NE. 0.0)  WRITE (6,37)  N, RC, ROFF, PHI0, PHIN
C
   37 FORMAT (1H1,39X,33HGEOMETRY DATA FOR SPHERE - TOROID //35X,22HNUMB
     1ER OF STATIONS -  ,I4//6X,7HRC     =,1PF13.4,7X,7HROFF   =,F13.4,7X,
     2 7HPHI0   =,F13.4,7X,7HPHIN   =,F13.4 )
C
      ANGSP = PHIN - PHI0
      DEL =  ANGSP/(FN -.1.0)
      AM = 1.0
      AMU = SIGN(AM,DEL)
      XSI(1) =  0.0
      BPHI = PHI0
      BSINP = SIND(PHI0)
      BCOSP = COSD(PHI0)
      R(1) = RC * BSINP + ROFF
      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)
      WFEX(I) = A0/RC * AMU
      IF (ROFF .EQ. 0.0) GO TO 38
      WTHX(I) = A0 * BSINP/R(I)
      GO TO 39
   38 WTHX(I) = WFEX(I)
   39 RHOX(I) = R(I)/A0
      BPHI = APHI
      BSINP = ASINP
      BCOSP = ACOSP
   40 CONTINUE
C
```

```
      DFL = ABS(DFL)                                                    00002550
      WFEX(N) = A0/RC*AMU                                               00002560
      IF (ROFF .EQ. 0.0) GO TO 45                                       00002570
      WTHX(N) = A0 * RSINP /R(N)                                        00002580
      GO TO 46                                                          00002590
   45 WTHX(N) = WFEX(N)                                                 00002600
      IF (RCIR .EQ. 1.0) GO TO 47                                       00002610
   46 RHOX(N) = R(N)/A0                                                 00002620
      GO TO 48                                                          00002630
   47 RHOX(N) = 0.0                                                     00002640
   48 DFL = DFL * RC * 0.01745329                                       00002650
      GO TO 95                                                          00002660
C                                                                       00002670
   50 IF (GMT .GT. 3.0) GO TO 60                                        00002680
C                                                                       00002690
      WRITE (6,55)                                                      00002700
   55 FORMAT (1H1,43HARBITRARY FUNCTIONS CANNOT BE HANDLED, YET. )      00002710
C                                                                       00002720
      GO TO 140                                                         00002730
C                                                                       00002740
C                         GENERAL DISCRETE POINTS                 **    00002750
C                                                                       00002760
   60 M  =  EM                                                          00002770
      MM = M - 1                                                        00002780
      MM2 = M- 2                                                        00002790
C                                                                       00002800
      IF (PFLAG .NE. 0.0) WRITE(6,62)     N, (RIPT(I), XIPT(I), I = 1,M)00002810
C                                                                       00002820
   62 FORMAT (1H1,39X,31HGEOMETRY DATA - DISCRETE POINTS //35X,22HNUMBER00002830
     1 OF STATIONS -   ,I4//16X,1HR,16X,2HXI//(3X,1P2E20.7) )           00002840
C                                                                       00002850
      SARB(1) = 0.0                                                     00002860
      IF(GIN .LT. 0.) GO TO 77                                          00002870
      DO 75 IL = 1,MM                                                   00002880
      SURB = 0.0                                                        00002890
      DLT = XIPT(IL+1) - XIPT(IL)                                       00002900
      K = 10                                                            00002910
      AK = K                                                            00002920
      DDL = DLT/AK                                                      00002930
      KP1 = K + 1                                                       00002940
      DO 65 JI = 1,KP1                                                  00002950
      AJI = JI - 1                                                      00002960
      XJ(JI) = XIPT(IL) + AJI * DDL                                     00002970
```

```
   65 CONTINUE                                                          00002980
C                                                                       00002990
      CALL CODIMA (KP1,XJ, RRJ, XIPT, RIPT, M, 1.0)                     00003000
      DO  69 I = 2,K                                                    00003010
   69 RJ(I) =  (RRJ(I-1) + RRJ(I) + RRJ(I+1) )/3.0                      00003020
      RJ(1) = RRJ(1)                                                    00003030
      RJ(KP1) = RRJ(KP1)                                                00003040
C                                                                       00003050
      DO 70 JR = 1,K                                                    00003060
      DLR(JR) = RJ(JR+1) - RJ(JR)                                       00003070
      DLS    =  SQRT(DLR(JR)**2 + DDL**2)                               00003080
   70 SURB = SURB + DLS                                                 00003090
      SARB(IL+1) = SARB(IL) + SURB                                      00003100
   75 CONTINUE                                                          00003120
      GO TO 80                                                          00003130
   77 DO 78 I = 1,M                                                     00003140
   78 SARB(I) = XIPT(I)                                                 00003150
   80 DFL = SARB(M) /(FN - 1.0)                                         00003160
C                                                                       00003170
      SURF(1) = 0.0                                                     00003180
      DO 82 I = 1,NN                                                    00003190
   82 SURF(I+1) = SURF(I) + DFL                                         00003200
      CALL CODIMA(N, SURF,RCRV, SARB, RCURV, M, 1.0)                    00003210
      CALL CODIMA(N,SURF, RCRZ, SARB, RCURZ, M, 1.0)                    00003220
C                                                                       00003230
      CALL CODIMA (N,SURF, R, SARB, RIPT, M, 1.0)                       00003240
C                                                                       00003250
      CALL CODIMA (N, SURF, XSI, SARB, XIPT, M, -1.0)                   00003260
      MLN = N - 2                                                       00003270
      NSM = 1                                                           00003280
   84 DO 85 I = 3,MLN                                                   00003290
      RR(I) = (-3.*R(I-2) + 12.*R(I-1) + 17.*R(I) + 12.*R(I+1) - 3. *   00003300
     1 R(I+2) )/ 35.0                                                   00003310
   85 CONTINUE                                                          00003320
      RR(NN) = R(NN)                                                    00003330
      RR(2) = R(2)                                                      00003340
      RR(N) = R(N)                                                      00003350
      RR(1) = R(1)                                                      00003360
      IF (NSM .EQ. 25) GO TO 88                                         00003370
      NSM = NSM + 1                                                     00003380
      DO  87 I = 1,N                                                    00003390
   87 R(I) = RR(I)                                                      00003400
      GO TO  84                                                         00003410
```

```
   88 RHOX(1) = RR(1)/A0
      DELSQ = DEL * DEL
      DO 89 I = 1,NN
   89 RHOX(I+1) = RR(I+1) /A0
      GO TO 110
C
C                    COMPUTE GAMA                              **
C
   95  DEL = DEL/ A0
       DELSQ = DEL * DEL
       DO 105 I = 1,N
      DENM = 12. * RHOX(I) * DEL
      DENMP= 2. * RHOX(I) * DEL
      IF(RHOX(I) .EQ. 0.)  GO TO 97
      IF (I .NE. 1) GO TO 98
      IF (BCIT .EQ. 1.0) GO TO 103
      GAMA(I) = (3.*(RHOX(I+1) - RHOX(I)) + RHOX(I+1) - RHOX(I+2))/DENMP
      GO TO 105
   97 GAMA(I)  =  0.0
      GO  TO  105
   98 IF (I .EQ. N) GO TO 100
      IF (I .EQ. 2) GO TO 99
      IF (I .EQ. N-1) GO TO 99
      GAMA(I) = (RHOX(I-2) - 8. *(RHOX(I-1) -      RHOX(I+1))- RHOX(I+2)
     1 )/DENM
      GO TO 105
   99 GAMA(I) = (RHOX(I+1) - RHOX(I-1)) /DENMP
      GO TO 105
  100 IF (BCIB .EQ. 1.0)  GO TO 103
      GAMA(I) =(3.*(RHOX(I)-RHOX(I-1)) + RHOX(I-2) - RHOX(I-1)) /DENMP
      GO  TO  105
  103 GAMA(I)  =  0.
  105 CONTINUE
       GO TO 123
C
  110 DO 115 I = 1,N
      WFEX(I) = A0/RCRV(I)
      WTHX(I) = A0/RCRZ(I)
      IF (RHOX(I) .EQ. 0.0) GO TO 113
      PRO = (RHOX(I) * WTHX(I))**2
      IF (PRO .GT. 1.0) GO TO 114
      GAMA(I) = SQRT(1.-PRO)/RHOX(I)
      GO TO 115
```

```
  113 GAMA(I) = 0.0                                                     00003850
      GO TO 115                                                         00003860
  114 GAMA(I) = 0.0                                                     00003870
  115 CONTINUE                                                          00003880
C                                                                       00003890
  123 DO 127 I = 1,N                                                    00003900
      WFDNM  =  2. * DFL                                                00003910
      IF (I .NE. 1) GO TO 124                                           00003920
      WFEPX(I) = (4. * WFEX(I+1) - 3. * WFEX(I) - WFEX(I+2)) /WFDNM     00003930
      GO TO 127                                                         00003940
  124 IF (I .FQ. N) GO TO 126                                           00003950
      WFEPX(I) = (WFEX(I+1) - WFEX(I-1)) /WFDNM                         00003960
      GO TO 127                                                         00003970
  126 WFEPX(I) = (WFFX(I-2) + 3. * WFEX(I) - 4. * WFEX(I-1)) /WFDNM     00003980
  127 CONTINUE                                                          00003990
C                                                                       00003999
      WRITE ( 3) WTHX, WFEX, GAMA, RHOX, WFEPX                          00004000
C                                                                       00004010
  129 IF (PFLAG .EQ. 0.0) GO TO 140                                     00004020
      WRITE (6,130) DEL, (I, R(I), XSI(I), WTHX(I), WFEX(I), RHOX(I),   00004030
     1 GAMA(I), I = 1,N)                                                00004050
C                                                                       00004060
  130 FORMAT (1H-, 5X, 7HDFL   =,1PE13.4 //                             00004070
     1              3X,1HI,9X,4HR(I),12X,5HXI(I),10X,8HW(THETA),11X,    00004071
     2 5HW(XI),11X,7HRHOX(I),10X,7HGAMA(I) //(I4, 1P6E17.7) )           00004072
C                                                                       00004090
  140 RFTURN                                                            00004100
C                                                                       00004110
 1000 FORMAT(1H1,47X,12HGENFRAL DATA/// 3X,7HA0    =,1PE13.4, 8X,7HHO   00004120
     1 =,E13.4, 8X,7HF0    =,E13.4, 8X,7HSIG0  =,E13.4// 3X,7HPOI   =,  00004121
     2 E13.4, 8X,7HFNF   =,E13.4, 8X,7HBCIT  =,E13.4, 8X,7HBCIB  =,     00004122
     3 E13.4//3X,7HPFLAG =,E13.4, 8X,7HCFXT  =,E13.4, 8X,7HDFLT  =,     00004123
     4 E13.4//6X,20HPRINT ANGLES (THT) - // 24X,6E13.4 //6X,33HFOURIER H00004124
     5ARMONIC PRINTS (FPRNT) - // 24X, 4E13.4                           00004125
     6                                           ///1H-,45X,17HBOUNDAR00004126
     7Y MATRICES /6X,15HTOP BOUNDARY **// 6X,5HOMEGA /5(5E17.7/)// 6X,  00004127
     8 6HLAMBDA /5(5E17.7/)// 6X,3HL -/ 5E17.7////6X,18HBOTTOM BOUNDARY 00004128
     9** // 6X,5HOMEGA /5(5E17.7/)// 6X,6HLAMBDA /5(5E17.7/)// 6X,3HL -/00004129
     X 5E17.7  )                                                        00004130
      END                                                               00009999
```

3.12d DATLYR Subroutine (STFDY)

```
$IBFTC STFDY                                                            00000010
C              FOURIER STIFFNESS COEFFICIENTS GENERATOR ** FUNCTIONS    00000020
C                                                                       00000030
      SUBROUTINE DATLYR                                                 00000040
C                                                                       00000050
C     ***  STIFFNESS COFFF. ARE STORED IN SECTIONS OF ALL FOURIER       00000060
C          COMPONENTS /MERIDIONAL STATION, UP TO BLOCKS OF 100          00000061
C                                                                       00000120
      DIMENSION  COFFC(2200)                                            00000130
      DIMENSION  SCB1(100), SCB2(100), SCB3(100), SCG1(100), SCG2(100), 00000150
     1 SCG3(100), SCD1(100), SCD2(100), SCD3(100), SCG13(100),          00000160
     2 SCNTSI(100), SCNTTH(100), SCMTSI(100), SCMTTH(100), DCM1(100),   00000170
     3 DCM4(100), DCC1(100), DCC2(100), DCC3(100), DCK1(100), DCK2(100),00000180
     4 DCK3(100)                                                        00000190
C                                                                       00000199
      COMMON  GDA(25), DEL, N, NNF, NTH,                                00000200
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                          00000210
C                                                                       00000220
C                                                                       00000230
      EQUIVALENCE (GDA( 1),   A0),            (GDA( 2),   H0),          00000240
     1            (GDA( 3),   E0),            (GDA( 4), SIG0),          00000250
     2            (GDA( 5),  POI),            (GDA( 6),  ENF),          00000260
     3            (GDA( 7), BCIT),            (GDA( 8), BCIB),          00000270
     4            (GDA( 9),PFLAG),            (GDA(10), CEXT),          00000280
     5            (GDA(11), DELT),            (GDA(12),  THT),          00000281
     6            (GDA(18),FPRNT)                                       00000282
C                                                                       00000309
      EQUIVALENCE (COFFC(    1),   SCB1),       (COEFC( 101),   SCB2), 00000310
     1            (COFFC( 201),   SCB3),       (COEFC( 301),   SCG1), 00000320
     2            (COFFC( 401),   SCG2),       (COFFC( 501),   SCG3), 00000330
     3            (COFFC( 601),   SCD1),       (COFFC( 701),   SCD2), 00000340
     4            (COFFC( 801),   SCD3),                               00000350
     5 (COEFC( 901), SCG13), (COEFC(1001),SCNTSI), (COEFC(1101),SCNTTH),00000360
     6 (COEFC(1201),SCMTSI), (COEFC(1301),SCMTTH), (COEFC(1401),  DCM1),00000370
     7 (COEFC(1501),  DCM4), (COEFC(1601),  DCC1), (COEFC(1701),  DCC2),00000380
     8 (COEFC(1801),  DCC3), (COEFC(1901),  DCK1), (COEFC(2001),  DCK2),00000390
     9 (COFFC(2101),  DCK3)                                             00000400
C                                                                       00000420
C                                                                       00000430
      IF(PFLAG .LT. 0.)  WRITE(6,10)                                    00000431
   10 FORMAT(1H1/6X, 96HCHECKPRINT OF COEFC BLOCKS STORED IN GROUPS OF (00000432
     12*ENF) PER MERIDIONAL STATION.  THE COEFFICIENTS /103H PRINTED ARE00000433
     2 SCB1, SCD1, SCNTSI, SCMTSI, DCM1, DCM4, DCC1, DCC2, DCC3, DCK1, D00000434
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
     3CK2, DCK3 (IN THAT ORDER) / 62H AND ARE SEPARATED FROM EACH OTHER 00000435
     4BY THE THREE ...... FIELDS.  ///)                                 00000436
      ENTH  =  90.                                                      00000440
      HO2 = HO * HO                                                     00000450
      SS3 = 2./3.1415927                                                00000460
      NTH  = ENTH                                                       00000470
      ENNF2 = ENF + ENF                                                 00000480
      NNF  =  ENF                                                       00000490
      NNF2  = 2 * NNF                                                   00000500
      IN = I                                                            00000510
C                 DETERMINE SIZE OF BLOCK                        **     00000518
C                                                                       00000519
      MNF  = N * NNF2                                                   00000520
   40 IF (MNF .GT. 100) GO TO 50                                        00000530
C                                            LESS THAN ONE BLOCK MORE   00000539
      LN = N                                                            00000540
      GO TO 60                                                          00000550
   50 IF (MNF .LT. 200) GO TO 55                                        00000560
C                                          AT LEAST 2 FULL BLOCKS MORE  00000569
      LN = 100/NNF2                                                     00000570
      GO TO 58                                                          00000580
C                                                                       00000584
C                             GREATER THAN ONE BLOCK, LESS THAN TWO     00000585
C                          AVOID HAVING ONLY TWO STATIONS IN A BLOCK.   00000586
C                                                                       00000587
   55 LN = 50/NNF2                                                      00000590
   58 LN = IN + LN - 1                                                  00000600
C                                                                       00000620
   60 DFLTH = 3.1415927/ ENTH                                           00000630
C                                                                       00000640
C                                        ZERO COEFFICIENT AREA          00000649
   63 DO 65  I = 1,2200                                                 00000650
   65 COEFC(I) = 0.0                                                    00000660
C                                                                       00000670
   70 DO 100 I = IN, LN                                                 00000680
C                            ESTABLISH MERIDIONAL DISTANCE              00000689
      EI = I - 1                                                        00000690
      PEL = EI * DEL                                                    00000700
      K1 = NNF2 * (I - IN)                                              00000710
C                                                                       00000719
      DO 100  NN = 1,NNF2                                               00000720
      K2 = K1 + NN                                                      00000730
      ENN = NN - 1                                                      00000740
```

```
C                                                                          00000770
   75 DO 95 J = 1,NTH                                                      00000780
      EJ = J - 1                                                           00000790
      ZTA = EJ * DELTH + DELTH * 0.5                                       00000800
      IF (NN .EQ. 1) GO TO 90                                              00000810
C                                                                          00000820
C                                         OTHER FOURIER COMPONENTS         00000839
   80 SCB1(K2) = SCB1(K2) + BBB(PEL,ZTA)      * COS (FNN *  ZTA)           00000840
      SCD1(K2) = SCD1(K2) + DDD(ZTA)          * COS (ENN *  ZTA)           00000845
      SCNTSI(K2) = SCNTSI(K2) + ENTT(PEL,ZTA) * COS(ENN * ZTA)             00000850
      SCMTSI(K2) = SCMTSI(K2) + EMTT(PEL,ZTA) * COS(ENN * ZTA)             00000855
      DCM1(K2) =DCM1(K2)+  DMM1(PEL,ZTA)  * COS(ENN* ZTA)                  00000860
      DCM4(K2) =DCM4(K2)+  DMM4(PEL,ZTA)  * COS(ENN* ZTA)                  00000870
      DCK1(K2) =DCK1(K2)+  DKK1(PEL,ZTA)  * COS(ENN* ZTA)                  00000880
      DCC1(K2) =DCC1(K2)+  DMP1(PEL,ZTA)  * COS(ENN* ZTA)                  00000885
      DCK2(K2) =DCK2(K2)+  DKK2(PEL,ZTA)  * COS(ENN* ZTA)                  00000890
      DCC2(K2) =DCC2(K2)+  DMP2(PEL,ZTA)  * COS(ENN* ZTA)                  00000895
      DCK3(K2) =DCK3(K2)+  DKK3(PEL,ZTA)  * COS(ENN* ZTA)                  00000900
      DCC3(K2) =DCC3(K2)+  DMP3(PEL,ZTA)  * COS(ENN* ZTA)                  00000905
      GO TO 95                                                             00000910
C                                         FIRST FOURIER COMPONENT          00000919
   90 SCB1(K2) = SCB1(K2) + BBB(PEL,ZTA) / 2.0                             00000920
      SCD1(K2) = SCD1(K2) + DDD(ZTA) / 2.0                                 00000925
      SCNTSI(K2) = SCNTSI(K2) + ENTT(PEL,ZTA) / 2.0                        00000930
      SCMTSI(K2) = SCMTSI(K2) + EMTT(PEL,ZTA) / 2.0                        00000935
      DCM1(K2) =DCM1(K2) + DMM1(PEL,ZTA)/2.0                               00000940
      DCM4(K2) =DCM4(K2) + DMM4(PEL,ZTA)/2.0                               00000950
      DCK1(K2) =DCK1(K2) + DKK1(PEL,ZTA)/2.0                               00000960
      DCC1(K2) =DCC1(K2) + DMP1(PEL,ZTA)/2.0                               00000965
      DCK2(K2) =DCK2(K2) + DKK2(PEL,ZTA)/2.0                               00000970
      DCC2(K2) =DCC2(K2) + DMP2(PEL,ZTA)/2.0                               00000975
      DCK3(K2) =DCK3(K2) + DKK3(PEL,ZTA)/2.0                               00000980
      DCC3(K2) =DCC3(K2) + DMP3(PEL,ZTA)/2.0                               00000985
   95 CONTINUE                                                             00000990
C                                                                          00001000
C                                                        NORMALIZE         00001009
      S3 = SS3/(EO * HO)                                                   00001010
      SCB1(K2) = S3 * DELTH * SCB1(K2)                                     00001020
      S4 = S3 * A0*A0                                                      00001030
      DCM1(K2) = S4* DELTH * DCM1(K2)                                      00001040
      DCM4(K2) = S3 * DELTH * DCM4(K2)                                     00001050
      DCK1(K2) = S4 * DELTH * DCK1(K2)                                     00001060
      DCC1(K2) = S4 * DELTH * DCC1(K2)                                     00001065
```

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      DCK2(K2) = S4 * DELTH * DCK2(K2)                                  00001070
      DCC2(K2) = S4 * DELTH * DCC2(K2)                                  00001075
      DCK3(K2) = S4 * DELTH * DCK3(K2)                                  00001080
      DCC3(K2) = S4 * DELTH * DCC3(K2)                                  00001083
      S3 = SS3 /(SIGO * HO)                                             00001085
      SCNTSI(K2) = S3 * DELTH * SCNTSI(K2)                              00001090
      S3 = SS3 * AO /(SIGO * HO2 * HO)                                  00001093
      SCMTSI(K2) = S3 * DELTH * SCMTSI(K2)                              00001096
      S3 = SS3/(EO * HO2 * HO)                                          00001100
      SCD1(K2) = S3 * DELTH * SCD1(K2)                                  00001110
C                                                                       00001120
   98 SS2 = (1. - POI) / 2.                                             00001130
      SCG13(K2) = SS2 * SCD1(K2)                                        00001140
      SCG1(K2) = SS2 * SCB1(K2)                                         00001150
      SCB2(K2) = SCB1(K2)                                               00001160
      SCB3(K2) = POI * SCB1(K2)                                         00001170
      SCG2(K2) = SS2 * SCB1(K2)                                         00001180
      SCG3(K2) = SCG1(K2)                                               00001190
      SCD2(K2) = SCD1(K2)                                               00001200
      SCD3(K2) = POI * SCD1(K2)                                         00001210
  100 CONTINUE                                                          00001280
C                                                                       00001290
      WRITE ( 9) LN, IN, COEFC                                          00001300
      NX  =  (LN - IN + 1) * NNF2                                       00001305
      XX  =  GDA(25)                                                    00001306
      IF(PFLAG .LT. 0.)                                                 00001309
     XWRITE (6,105)  IN, LN, (SCB1(I), I=1,NX), XX, XX, XX, (SCD1(I),   00001310
     1 I=1,NX), XX, XX, XX, (SCNTSI(I), I=1,NX), XX, XX, XX, (SCMTSI(I),00001311
     2 I=1,NX), XX, XX, XX, (DCM1(I), I=1,NX), XX, XX, XX, (DCM4(I), I  00001312
     3 = 1,NX), XX, XX, XX, (DCC1(I), I=1,NX), XX, XX, XX, (DCC2(I), I  00001313
     4 = 1,NX), XX, XX, XX, (DCC3(I), I=1,NX), XX, XX, XX, (DCK1(I), I  00001314
     5 = 1,NX), XX, XX, XX, (DCK2(I), I=1,NX), XX, XX, XX, (DCK3(I), I  00001315
     6 = 1,NX)                                                          00001316
  105 FORMAT(/10X,11HFOR STATION, I3,16H THROUGH STATION, I4///         00001320
     1       ( 1P6E17.7) )                                              00001321
C                                                                       00001330
      IF (LN .EQ. N) GO TO 110                                          00001340
      IN = LN + 1                                                       00001350
      NCN = N - LN                                                      00001360
      MNF = NCN * NNF2                                                  00001370
      GO TO 40                                                          00001380
  110 RETURN                                                            00001390
C                                                                       00001400

      END                                                               00001410
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

3.12e DATLD Subroutine (DLDY)

```
$IBFTC DLDY                                                             00000010
C              FOURIER LOAD COEFFICIENTS GENERATOR BY FUNCTIONS ONLY    00000020
C                                                                       00000030
      SUBROUTINE  DATLD                                                 00000040
C                                                                       00000050
C                                                                       00000060
      DIMENSION  PFE(10,50), PTH(10,50), PN(10,50)                      00000340
      EQUIVALENCE (GDA( 1),    A0),               (GDA( 2),    H0),     00000440
     1            (GDA( 3),    E0),               (GDA( 4), SIG0),      00000450
     2            (GDA( 5),   POI),               (GDA( 6),   ENF),     00000460
     3            (GDA( 7), BCIT),                (GDA( 8), BCIB),      00000470
     4            (GDA( 9),PFLAG),                (GDA(10), CEXT),      00000480
     5            (GDA(11), DELT),                (GDA(12),   THT),     00000481
     6            (GDA(18),FPRNT)                                       00000482
C                                                                       00000490
      COMMON  GDA(25), DFL, N, NNF, NTH,                                00000500
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                          00000510
C                                                                       00000520
C              INITIALIZE *          *          *          *            00000525
      NAB = 0                                                           00000530
      SS3 = 2. /3.1415927                                               00000550
      S3 = SS3 * A0/(SIG0 * H0)                                         00000560
      NUN = 2                                                           00000570
      IF (N .GT. 50)  NUN = 3                                           00000580
      IF (TCTR .GT. 1.0)  AF = FILE (9,NUN)                             00000590
C                                                                       00000600
      DO 20 I = 1,50                                                    00000610
      DO 20 K = 1,10                                                    00000620
      PFE(K,I) = 0.0                                                    00000630
      PTH(K,I) = 0.0                                                    00000650
      PN(K,I)  = 0.0                                                    00000670
   20 CONTINUE                                                          00000690
C                                                                       00000720
      IF(PFLAG .LT. 0.)  WRITE(6,30)                                    00000730
   30 FORMAT(1H1/6X, 98HCHECKPRINT OF LOAD COEF. STORED IN GROUPS OF ALL00000740
     1 ENF PER MERIDIONAL STATION.  THE COEFFICIENTS ARE  / 81H PFE, PTH00000741
     2, PN (IN THAT ORDER) AND ARE SEPARATED FROM EACH OTHER BY ...... F00000742
     3IELDS.  ///)                                                      00000743
      NI = N                                                            00000770
C                                                                       00000790
C                                                  SPECIAL  FUNCTIONS   00000795
C                                                                       00000800
   50 EI = 0.0                                                          00000810
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

```
      NI1 = 1                                                           00000820
      NI2  =  N                                                         00000830
      FNTH  =  NTH                                                      00000840
      DELTH = 3.1415927 / FNTH                                          00000850
C                                                                       00000870
C                   EACH BLOCK OF LOADS CANNOT CONTAIN MORE THAN 50 STAS. 00000873
C                                                                       00000876
      IF (NI .GT. 50) NI = 50                                           00000880
   70 DO 100 I = 1,NI                                                   00000890
      EI = EI + 1.0                                                     00000900
      PEL = (EI - 1.0) * DEL                                            00000910
C                                                                       00000919
      DO 100 NN = 1,NNF                                                 00000920
      ENN = NN- 1                                                       00000930
      TU = DELT * TCTR                                                  00000940
C                                                                       00000960
      DO 95 J = 1,NTH                                                   00000970
      EJ = J - 1                                                        00000980
      ZTA = EJ * DELTH + DELTH * 0.5                                    00000990
      IF (NN .EQ. 1)  GO TO 90                                          00001000
C                                                                       00001010
      PTH(NN,I) = PTH(NN,I)+PPPH(PEL,ZTA,TU)* SIN(ENN * (ZTA-1.5707963))00001030
      PFE(NN,I) = PFE(NN,I)  +PPPF(PEL,ZTA,TU)*COS(ENN * ZTA)           00001040
      PN(NN,I) = PN(NN,I) + PPPN(PEL,ZTA,TU)* COS(ENN * ZTA)            00001050
      GO TO 95                                                          00001060
C                                                                       00001069
   90 PTH(NN,I) = PTH(NN,I) + PPPH(PEL,ZTA,TU) /2.                      00001080
      PFE(NN,I) = PFE(NN,I) + PPPF(PEL,ZTA,TU) /2.                      00001090
      PN(NN,I)= PN(NN,I) + PPPN(PEL,ZTA,TU)/2.0                         00001100
   95 CONTINUF                                                          00001110
C                                                                       00001120
      PTH(NN,I) = S3 * DELTH * PTH(NN,I)                                00001130
      PFE(NN,I) = S3 * DELTH * PFE(NN,I)                                00001140
      PN(NN,I) = S3 * DELTH * PN(NN,I)                                  00001150
  100 CONTINUE                                                          00001160
C                                                                       00001170
      IF (TCTR .EQ. 1.0) GO TO 105                                      00001180
      WRITE ( 9) PFE, PTH, PN                                           00001190
      GO TO 107                                                         00001200
  105 WRITE ( 3) PFE, PTH, PN                                           00001210
  107 XX  =  GDA(25)                                                    00001220
      IF(N .GT. 50 .AND. NAB.EQ. 0)  NI2 = 50                           00001222
      IF(PFLAG .LT. 0.)                                                 00001229
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
      XWRITE (6,108) NI1, NI2, ((PFE(NN,I), NN=1,NNF), I=1,NI), XX, XX, X00001230
     1X, ((PTH(NN, I), NN=1,NNF), I=1,NI), XX, XX, XX, ((PN(NN,I), NN=1,00001231
     2NNF), I=1,NI)                                                     00001232
  108 FORMAT(/10X,11HFOR STATION, I3,16H THROUGH STATION, I4///         00001235
     1       ( 1P6E17.7) )                                              00001236
C                                                                       00001240
      NAB = NAB + NI                                                    00001250
      IF (NAB .EQ. N) GO TO 600                                         00001260
C                                                                       00001264
C                   MORE THAN 50 STATIONS TO STORE              *       00001265
C                                                                       00001266
      NI = N - NI                                                       00001270
      NI1  =  51                                                        00001281
      NI2  =  N                                                         00001282
      DO 115 I = 1,50                                                   00001290
      DO 110 J = 1,10                                                   00001300
      PTH(J,I) = 0.0                                                    00001310
      PFE(J,I) = 0.0                                                    00001320
  110 PN(J,I) = 0.0                                                     00001330
  115 CONTINUE                                                          00001340
C                                                                       00001350
      GO TO 70                                                          00001360
C                                                                       00001370
  600 IF (T[illegible]R .NE. 1.0) GO TO 610                                     00002820
      REWIND 3                                                          00002830
      RETURN                                                            00002840
C                                                                       00002850
  610 IF (N .GT. 50) BACKSPACE  9                                       00002860
      BACKSPACE  9                                                      00002870
      RETURN                                                            00002880
C                                                                       00002890
      END                                                               00002910
```

3. 12f PANDX Subroutine (PXDYN)

```
$IBFTC PXDYN                                                            00000010
C        GENERATES THE 'P' AND 'X' MATRICES                    **      00000020
C           NOTE    RECURSION TERMS ARE ALSO GENERATED         **      00000030
C                                                                       00000040
      SUBROUTINE  PANDX                                                 00000050
C                                                                       00000060
C     A0          REFERENCE LENGTH (IN)                                 00000070
C     H0          REFERENCE THICKNESS (IN)                              00000080
C     E0          REFERENCE YOUNGS MODULUS  (PSI)                       00000090
C     SIG0        REFERENCE STRESS  (PSI)                               00000100
C     NMF         NO. OF TERMS IN THE FOURIER EXPANSION.                00000110
C     LAM         LAMBDA  =  H0 /A0                                     00000120
C     WFE         OMEGA (XI)                                            00000130
C     WTH         OMEGA (THETA)                                         00000140
C      ARRAYS USED                                                      00000150
C          COEFC   -   CONTAINS STIFFNESS COEFF CALCULATED IN DATLYR    00000160
C          P1SCB1  -   TEMP STORAG   OR STIFFNESS COEFF AT LAST TWO     00000170
C          P2SCB1  -              TIONS OF THE BLOCK                    00000171
C      PANDX FLAGS                                                      00000190
C          JPATH = 0    PATH IND. THRU ENF LOOP WHEN F, G, H INCOMPLETE 00000196
C          JPATH = 1    PATH IND. THRU ENF LOOP TO SKIP FGHPE AND BND.  00000197
C          KPATH = 0    PATH IND. THRU ENF LOOP WHEN L, M, N INCOMPLETE 00000198
C          KPATH = 1    PATH IND. THRU ENF LOOP TO SKIP DYLMN AND BND.  00000199
C          IRTE .NE. 1   FIRST STATION  -  NOT FIRST BLOCK              00000200
C          IRTE .EQ. 1   LAST STATION - PREVIOUS BLOCK                  00000210
C          IFGFG = 10   F, G, H, PE  HAVE NOT BEEN COMPLETED, YET.      00000220
C          IFGFG = 0    P AND X  HAVE BEEN COMPUTED FOR IRTE = 1.       00000230
C          IFGFG = 1    P AND X  COMPUTED.  INCREMENT STA. INDEX.       00000240
C          IRSFG = 10   R, S, LT,  HAVE NOT BEEN COMPLETED.             00000250
C          IRSFG = 1   INITIAL BOUNDARY COMPUTED.                       00000260
C          IRSFG = 0   TERMINAL BOUNDARY COMPUTED.                      00000270
C          IFDYN = 10   AL, AM, AN HAVE NOT BEEN COMPLETED.             00000280
C          IFDYN = 1    AK, AM, AN COMPUTED.                            00000290
C          IFMX  = 10   PE NOT COMPLETED.                               00000300
C          IFMX  =  1   PE COMPUTED.                                    00000310
C      COUNTERS  -                                                      00000312
C          MM   - ABSOLUTE STATION NUMBER.        *         *           00000313
C          I    - STATION NO. WITHIN EACH BLOCK OF STIFF. COEFF.        00000314
C          MMN  - STATION NO. WITHIN BLOCK OF LOADS.                    00000315
C          IFLG - STIFF. COEFF. BLOCK. *          *                     00000316
C                                                                       00000320
      EQUIVALENCE  (BMTX(  1), OMG0),            (BMTX( 26), OMGN),     00000330
     1             (BMTX( 51), ALM0),            (BMTX( 76), ALMN),     00000340
```

```
     2            (BMTX(101), OMG1),               (BMTX(126), ALM1),     00000350
     3            (BMTX(151),  LL0),               (BMTX(156), LLLN)      00000360
C                                                                         00000370
      EQUIVALENCE (GDA( 1),    A0),             (GDA( 2),    H0),         00000380
     1            (GDA( 3),    E0),             (GDA( 4),  SIG0),         00000390
     2            (GDA( 5),   POI),             (GDA( 6),   ENF),         00000400
     3            (GDA( 7),  BCIT),             (GDA( 8),  BCIB),         00000410
     4            (GDA( 9),PFLAG),              (GDA(10), CEXT),          00000420
     5            (GDA(11), DELT),              (GDA(12),   THT),         00000421
     6            (GDA(18),FPRNT)                                         00000422
C                                                                         00000440
      DIMENSION  WTHX(100), WFEX(100), RHOX(100), GAMA(100), WFEPX(100)   00000450
      DIMENSION  ALM0(5,5), ALMN(5,5), OMG0(5,5), OMGN(5,5)               00000460
      DIMENSION  ALM1(5,5), OMG1(5,5)                                     00000470
      REAL  LL0(5),  LLLN(5),                       MFE(10), MTP(10)      00000480
      DIMENSION  P1SCB1(20), P2SCB1(20), P1SCD1(20), P2SCD1(20),          00000490
     1  TFE(10), P1SG13(20), P2SG13(20), P1ENT(20), P2ENT(20), PN50(10),00000491
     2  TTP(10), P1SCG1(20), P2SCG1(20), P1FMT(20), P2EMT(20),            00000492
     3  P2DCK1(20), P2DCK2(20), P2DCK3(20), P2DCM1(20), P2DCM4(20),       00000493
     4  P2DCC1(20), P2DCC2(20), P2DCC3(20), PFE50(10), PTH50(10)          00000494
      DIMENSION   PFE(10, 50),   PTH(10, 50),   PN(10, 50)                00000540
      DIMENSION  P(50,50), X(50)                                          00000570
C                                                                         00000580
      DIMENSION  COEFC(2200)                                              00000590
      DIMENSION  SCB1(100), SCB2(100), SCB3(100), SCG1(100), SCG2(100),   00000600
     1 SCG3(100), SCD1(100), SCD2(100), SCD3(100), SCG13(100),            00000610
     2 SCNTSI(100), SCNTTH(100), SCMTSI(100), SCMTTH(100), DCM1(100),     00000620
     3 DCM4(100), DCC1(100), DCC2(100), DCC3(100), DCK1(100), DCK2(100),00000630
     4 DCK3(100)                                                          00000640
C                                                                         00000649
      EQUIVALENCE (COEFC(    1),  SCB1),            (COEFC( 101),  SCB2), 00000650
     1            (COEFC( 201),  SCB3),             (COEFC( 301),  SCG1), 00000660
     2            (COEFC( 401),  SCG2),             (COEFC( 501),  SCG3), 00000670
     3            (COEFC( 601),  SCD1),             (COEFC( 701),  SCD2), 00000680
     4            (COEFC( 801),  SCD3),                                   00000690
     5 (COEFC( 901), SCG13), (COEFC(1001),SCNTSI), (COEFC(1101),SCNTTH),00000700
     6 (COEFC(1201),SCMTSI), (COEFC(1301),SCMTTH), (COEFC(1401),  DCM1),00000710
     7 (COEFC(1501),  DCM4), (COEFC(1601),  DCC1), (COEFC(1701),  DCC2),00000720
     8 (COEFC(1801),  DCC3), (COEFC(1901),  DCK1), (COEFC(2001),  DCK2),00000730
     9 (COEFC(2101),  DCK3)                                               00000740
C                                                                         00000760
      COMMON  GDA(25), DEL, N, NNF, NTH,                                  00000770
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                            00000780
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C                                                                        00000789
      REAL   LAM, LAMO2, LAM2O2, LAM2O4, LAM2O8, LAM2, KORO, KORO2,     00000790
     1         MFETK, MTHTK, MFETP,      LLI                             00000800
C                                                                        00000809
      COMMON /PXCMN/     MM, LLN, I, IFLG, LN, IRSFG, IFGFG,             00000810
     1 BB1KJ, BB2KJ, BB3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,    00000811
     2 GG13KJ, TFETK, TTHTK, MFETK, MTHTK, BB1P, BB3P, GG1P, GG2P,       00000812
     3 DD1P, DD3P, GG13P, TFETP, MFETP, OMG(5,5), ALM(5,5), LLI(5),      00000813
     4 WTH, WFE, GAM, RHO, WFEP, LAM, LAM2, LAMO2, LAM2O2, LAM2O4,       00000814
     5 LAM2O8, GAM2, WTMWF, WTMWF2, WFWT, PTHK, PNK, PFEK, P, X,         00000815
     6 DCM1KJ, DCM2KJ, DCM3KJ, DCM4KJ, DCM5KJ, DCC1KJ, DCC2KJ, DCC3KJ,   00000816
     7 DCK1KJ, DCK2KJ, DCK3KJ                                            00000817
      COMMON /BLOCK1/  EMM2 (50,50)                                      00000900
      COMMON /BLOCK2/  EMM3 (50)                                         00000910
C                                                                        00000920
      IF(PFLAG .EQ. -1.E+10)  WRITE (6,340)                              00000930
C                                       READ GEOMETRY PARAMETERS (100)   00000939
      READ  ( 3) WTHX, WFEX, GAMA, RHOX, WFEPX                           00000940
      N2 = 2 * NNF                                                       00000950
C                                                                        00000960
      IN = 1                                                             00000970
      MMN = 0                                                            00000980
      IFLG = 0                                                           00000990
C                                                                        00000999
      IF (TCTR .EQ. 1.0) GO TO 8                                         00001000
      READ ( 9) PFE, PTH, PN                                             00001010
C                                          READ PRESSURES (10, 50)       00001019
      REWIND  9                                                          00001020
      AF = FILE (9,1)                                                    00001030
      GO TO 15                                                           00001040
C                                                                        00001048
C                                   READ PRESSURES (10,50) TIME CYCLE 1  00001049
    8 READ ( 3) PFE, PTH, PN                                             00001050
C                                                                        00001056
C                                        READ STIFFNESS COEFF (100)      00001057
C                                      IN - INITIAL STATION IN BLOCK     00001058
C                                      LN - LAST STATION IN BLOCK        00001059
   10 READ  ( 9) LN, IN, COEFC                                           00001060
C                                                                        00001069
   15 IRTE = 1                                                           00001070
      MM = IN - 1                                                        00001080
      IFLG = IFLG + 1                                                    00001090
      LLN = LN - IN + 1                                                  00001100
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```
      I = 0                                                             00001110
      KK = NNF                                                          00001120
      DEL2 = 2. * DEL                                                   00001130
C                                                                       00001140
   20 I = I + 1                                                         00001150
      MM = MM + 1                                                       00001160
      MMN = MMN + 1                                                     00001170
      IF (TCTR .GT. 1.0 .AND. MM .EQ. 1) GO TO 20                       00001180
      IF (TCTR .GT. 1.0 .AND. MM .EQ. N)  RETURN                        00001190
      JPATH = 0                                                         00001200
      KPATH = 0                                                         00001210
      IF (MM .NE. 51)  GO TO 23                                         00001230
      DO  19     IX = 1,KK                                              00001232
      PFE50(IX)  =  PFE(IX,50)                                          00001234
      PTH50(IX)  =  PTH(IX,50)                                          00001236
   19 PN50(IX)   =  PN(IX,50)                                           00001238
      IF (TCTR .EQ. 1.0) GO TO 21                                       00001240
      AF = FILE(9,2)                                                    00001250
      READ ( 9) PFE, PTH, PN                                            00001260
      READ ( 9) PFE, PTH, PN                                            00001270
      REWIND  9                                                         00001280
      AF = FILE(9,2)                                                    00001290
      GO TO 22                                                          00001300
   21 READ ( 3) PFE, PTH, PN                                            00001310
   22 MMN = 1                                                           00001320
C                                                                       00001329
   23 DO 9998 J = 1,KK                                                  00001330
      IF (TCTR .GT. 1.0) GO TO 37                                       00001340
      IF (JPATH .EQ. 1) GO TO 37                                        00001350
      IF (KPATH .EQ. 1) GO TO 37                                        00001360
C                                                                       00001365
C                ESTABLISH BOUNDARY CONDITIONS ARRAY.                   00001366
C                                                                       00001367
      IF (MM .NE. 1) GO TO 33                                           00001370
      IF (J .EQ. 1) GO TO 31                                            00001380
      IF (BCIT .NE. 1.0) GO TO 31                                       00001390
      IF (J .GT. 2) GO TO 29                                            00001400
C                                           CLOSED APEX, 2ND HARMONIC   00001409
   27 DO 28 KN = 1,5                                                    00001410
      DO 28 JJ = 1,5                                                    00001420
      OMG(KN,JJ) = OMG1(KN,JJ)                                          00001430
      ALM(KN,JJ) = ALM1(KN,JJ)                                          00001440
   28 LLI(KN) = 0.0                                                     00001450
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```
      GO TO 37                                                          00001460
C                                        CLOSED APEX, .GT. 2ND HARMONIC 00001469
   29 DO 30 KN = 1,5                                                    00001470
      DO 30 JJ = 1,5                                                    00001480
      OMG(KN,JJ) = 0.0                                                  00001490
      ALM(KN,JJ) = 0.0                                                  00001500
      IF (KN .EQ. JJ) ALM(KN,JJ) = 1.0                                  00001510
   30 LLI(KN) = 0.0                                                     00001520
      GO TO 37                                                          00001530
C                                      1ST FOURIER COMPONENT, 1ST STA.  00001539
   31 DO 32 KN = 1,5                                                    00001540
      DO 32 JJ = 1,5                                                    00001550
      OMG(KN,JJ) = OMGO(KN,JJ)                                          00001560
      ALM(KN,JJ) = ALMO(KN,JJ)                                          00001570
   32 LLI(KN) = LLO(KN)                                                 00001580
      GO TO 37                                                          00001590
C                                                                       00001599
   33 IF (MM .NE. N) GO TO 37                                           00001600
C                                                          LAST STATION 00001609
      IF (J .EQ. 1) GO TO 34                                            00001610
      IF (BCIB .NE. 1.0) GO TO 34                                       00001620
      IF (J .GT. 2) GO TO 29                                            00001630
      GO TO 27                                                          00001640
C                                      1ST FOURIER COMPONENT, NTH STA.  00001649
   34 DO 35 KN = 1,5                                                    00001650
      DO 35 JJ = 1,5                                                    00001660
      OMG(KN,JJ) = OMGN(KN,JJ)                                          00001670
      ALM(KN,JJ) = ALMN(KN,JJ)                                          00001680
   35 LLI(KN) = LLLN(KN)                                                00001690
C                                                                       00001699
   37 DO 9998  K = 1,KK                                                 00001700
      IF (TCTR .GT. 1.0) GO TO 152                                      00001710
      IF (KPATH .EQ. 1) GO TO 152                                       00001720
      IF (I .NE. 1) GO TO 85                                            00001730
      IF (IFLG .NE. 1) GO TO 98                                         00001740
C                                                                       00001750
C                 RECURSION FORMS       *           *           *       00001751
C                                                                       00001752
   38 JMK = J - K                                                       00001760
      KMJA = 1 + IABS(K - J)                                            00001770
      KPJ = K + J - 1                                                   00001780
      TERM1 = 1.0                                                       00001790
      IF (JMK .EQ. 0) TERM1 = 0.0                                       00001800
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      TERM2 = 1.0                                                       00001810
      IF (K .EQ. 1) TERM2 = 0.0                                         00001820
      FCTR = 1. - TERM1 + TERM2                                         00001830
      FCTR2 = 1. - 2. * TERM2                                           00001840
C                                                                       00001850
      K2 = N2 * (I-1) + KPJ                                             00001860
      K5 = N2 * (I-1) + KMJA                                            00001870
      IF (JPATH .EQ. 1) GO TO 50                                        00001880
      K1 = N2 * I + KPJ                                                 00001890
      K3 = N2 * (I+1) + KPJ                                             00001900
      K4 = N2 * I + KMJA                                                00001910
      K6 = N2 * (I+1) + KMJA                                            00001920
      K7 = N2 * (I-2) + KPJ                                             00001930
      K8 = N2 * (I-2) + KMJA                                            00001940
      K9 = N2 * (I-3) + KPJ                                             00001950
      K10 = N2 * (I-3) + KMJA                                           00001960
C                                                                       00001970
      IF (MM .NE. 1) GO TO 55                                           00001980
C                                                                       00001988
C                 FORWARD DIFFERENCE FOR FIRST STATION.          *      00001989
      IF(J .NE. 1) GO TO 39                                             00001990
      TTP(K) = (4. * SCNTSI(K1) - 3. * SCNTSI(K2) - SCNTSI(K3)) /DEL2   00001991
      MTP(K) = (4. * SCMTSI(K1) - 3. * SCMTSI(K2) - SCMTSI(K3)) /DEL2   00001992
      TFE(K)   =  SCNTSI(K2)                                            00001993
      MFE(K)   =  SCMTSI(K2)                                            00001994
C                                                                       00001995
   39 BP1KPJ = (4. * SCB1(K1) - 3. * SCB1(K2) - SCB1(K3)) /DEL2         00002000
      DP1KPJ = (4. * SCD1(K1) - 3. * SCD1(K2) - SCD1(K3)) /DEL2         00002010
      G13KPJ = (4. * SCG13(K1) - 3. * SCG13(K2) - SCG13(K3)) /DEL2      00002020
      GP1KPJ = (4. * SCG1(K1) - 3. * SCG1(K2) - SCG1(K3)) /DEL2         00002040
C                                                                       00002050
      BP1KMJ = (4. * SCB1(K4) - 3. * SCB1(K5) - SCB1(K6)) /DEL2         00002060
      DP1KMJ = (4. * SCD1(K4) - 3. * SCD1(K5) - SCD1(K6)) /DEL2         00002080
      G13KMJ = (4. * SCG13(K4) - 3. * SCG13(K5) - SCG13(K6)) /DEL2      00002090
      GP1KMJ = (4. * SCG1(K4) - 3. * SCG1(K5) - SCG1(K6)) /DEL2         00002110
C                                                                       00002120
C                 DERIVATIVE OF STIFFNESS RECURSIONS.          *        00002121
C                                                                       00002122
   40 BB1P      =  0.5 *  (BP1KPJ + FCTR * BP1KMJ)                      00002130
      DD1P   =    0.5 * (DP1KPJ + FCTR * DP1KMJ)                        00002140
      GG13P = 0.5 * (FCTR * G13KMJ + FCTR2 * G13KPJ)                    00002150
      GG1P = 0.5 * (FCTR * GP1KMJ + FCTR2 * GP1KPJ)                     00002160
C                                                                       00002170
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C                  STIFFNESS RECURSION    *            *           *         00002171
C                                                                            00002172
   50 BB1KJ  = 0.5 * (SCB1(K2) + FCTR * SCB1(K5))                            00002180
      DD1KJ  = 0.5 * (SCD1(K2) + FCTR * SCD1(K5))                            00002190
      DCM1KJ = 0.5 * ( DCM1(K2) + FCTR * DCM1(K5))                           00002200
      DCM2KJ = 0.5 * ( FCTR * DCM1(K5) + FCTR2 * DCM1(K2))                   00002210
      DCM4KJ = 0.5 * ( DCM4(K2) + FCTR * DCM4(K5))                           00002220
      DCM5KJ = 0.5 * ( FCTR * DCM4(K5) + FCTR2 * DCM4(K2))                   00002230
      DCK1KJ = 0.5 * (DCK1(K2)+ FCTR * DCK1(K5))                             00002240
      DCK2KJ = 0.5 * ( FCTR * DCK2(K5) + FCTR2 * DCK2(K2))                   00002250
      DCK3KJ = 0.5 * (DCK3(K2) + FCTR * DCK3(K5))                            00002260
      GG13KJ = 0.5 * (FCTR * SCG13(K5) + FCTR2 * SCG13(K2))                  00002270
      GG1KJ = 0.5 * (FCTR * SCG1(K5) + FCTR2 * SCG1(K2))                     00002280
      GO TO 150                                                              00002290
C                                                                            00002300
   55 IF (MM .EQ. N) GO TO 65                                                00002310
      IF(J .NE. 1) GO TO 57                                                  00002311
      TTP(K) = (SCNTSI(K1) - SCNTSI(K7)) /DEL2                               00002312
      MTP(K) = (SCMTSI(K1) - SCMTSI(K7)) /DEL2                               00002313
      TFE(K)  =  SCNTSI(K2)                                                  00002314
      MFE(K)  =  SCMTSI(K2)                                                  00002315
   57 BP1KPJ = (SCB1(K1) - SCB1(K7)) /DEL2                                   00002316
      DP1KPJ = (SCD1(K1) - SCD1(K7)) /DEL2                                   00002330
      G13KPJ = (SCG13(K1) - SCG13(K7)) /DEL2                                 00002340
      GP1KPJ = (SCG1(K1) - SCG1(K7)) /DEL2                                   00002350
C                                                                            00002370
   60 BP1KMJ = (SCB1(K4) - SCB1(K8)) /DEL2                                   00002380
      DP1KMJ = (SCD1(K4) - SCD1(K8)) /DEL2                                   00002390
      G13KMJ = (SCG13(K4) - SCG13(K8)) /DEL2                                 00002400
      GP1KMJ = (SCG1(K4) - SCG1(K8)) /DEL2                                   00002410
      GO TO 40                                                               00002420
C                                                                            00002430
C                  BACKWARD DIFFERENCE FOR LAST STATION.       *             00002431
   65 IF(J .NE. 1) GO TO 70                                                  00002432
      TTP(K) = (SCNTSI(K9) + 3. * SCNTSI(K2) - 4. * SCNTSI(K7)) /DEL2        00002433
      MTP(K) = (SCMTSI(K9) + 3. * SCMTSI(K2) - 4. * SCMTSI(K7)) /DEL2        00002434
      TFE(K)  =  SCNTSI(K2)                                                  00002435
      MFE(K)  =  SCMTSI(K2)                                                  00002436
C                                                                            00002437
   70 BP1KPJ = (SCB1(K9) + 3. * SCB1(K2) - 4. * SCB1(K7)) /DEL2              00002440
      DP1KPJ = (SCD1(K9) + 3. * SCD1(K2) - 4. * SCD1(K7)) /DEL2              00002450
      G13KPJ = (SCG13(K9) + 3. * SCG13(K2) - 4. * SCG13(K7)) /DEL2           00002460
      GP1KPJ = (SCG1(K9) + 3. * SCG1(K2) - 4. * SCG1(K7)) /DEL2              00002470
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C                                                                       00002480
      BP1KMJ = (SCB1(K10) + 3. * SCB1(K5) - 4. * SCB1(K8)) /DEL2        00002490
      DP1KMJ = (SCD1(K10) + 3. * SCD1(K5) - 4. * SCD1(K8)) /DEL2        00002500
      G13KMJ = (SCG13(K10) + 3. * SCG13(K5) - 4.*SCG13(K8)) /DEL2       00002510
      GP1KMJ = (SCG1(K10) + 3. * SCG1(K5) - 4. * SCG1(K8)) /DEL2        00002520
      GO TO 40                                                          00002530
C                                                                       00002540
C                                                                       00002550
   85 IF (LN .EQ. N) GO TO 38                                           00002560
      IF (I .NE. 3) GO TO 93                                            00002570
C                                                 AT ARBITRARY STATION 3 00002577
C                SAVE COEFF. OF LAST TWO STAS. OF THIS BLOCK.  TO BE    00002578
C                USED TO COMPUTE DERIVATIVES ON NEXT BLOCK.  *          00002579
C                                                                       00002580
      KK2 = 2 * KK                                                      00002590
      K11 = N2 * (LLN-2)                                                00002600
      K12 = N2 * (LLN-1)                                                00002610
      DO 90 IK = 1, KK2                                                 00002620
      K13 = K11 + IK                                                    00002630
      K14 = K12 + IK                                                    00002640
      P1SCB1(IK) = SCB1(K13)                                            00002650
      P2SCB1(IK) = SCB1(K14)                                            00002660
      P1SCD1(IK) = SCD1(K13)                                            00002670
      P2SCD1(IK) = SCD1(K14)                                            00002680
      P1SG13(IK) = SCG13(K13)                                           00002690
      P2SG13(IK) = SCG13(K14)                                           00002700
      P1SCG1(IK) = SCG1(K13)                                            00002710
      P2SCG1(IK) = SCG1(K14)                                            00002720
      P2DCM1(IK) = DCM1(K14)                                            00002730
      P2DCM4(IK) = DCM4(K14)                                            00002740
      P2DCK1(IK) = DCK1(K14)                                            00002750
      P2DCK2(IK) = DCK2(K14)                                            00002760
      P2DCK3(IK) = DCK3(K14)                                            00002770
      P1ENT(IK) = SCNTSI(K13)                                           00002772
      P2ENT(IK) = SCNTSI(K14)                                           00002774
      P1EMT(IK) = SCMTSI(K13)                                           00002776
      P2EMT(IK) = SCMTSI(K14)                                           00002778
   90 CONTINUE                                                          00002780
C                                          IS COEFF BLOCK COMPLETED     00002789
   93 IF (I .EQ. LLN) GO TO 10                                          00002790
C                                                   NO                  00002799
      GO TO 38                                                          00002800
C                                                                       00002810
```

```
C                                                                       00002820
   98 JMK  = J - K                                                      00002830
      KMJA = 1 + IABS(K - J)                                            00002840
      KPJ = K + J - 1                                                   00002850
      TERM1 = 1.0                                                       00002860
      IF (JMK .EQ. 0) TFRM1 = 0.0                                       00002870
      TERM2 = 1.0                                                       00002880
      IF (K .EQ. 1) TERM2 = 0.0                                         00002890
      FCTR = 1. - TERM1 + TERM2                                         00002900
      FCTR2 = 1. - 2. * TERM2                                           00002910
C                                                                       00002920
      K1 = N2 * I + KPJ                                                 00002930
      K2 = N2 * (I-1) + KPJ                                             00002940
      K4 = N2 * I + KMJA                                                00002950
      K5 = N2 * (I-1) + KMJA                                            00002960
C                                                                       00002970
      IF (JPATH .EQ. 1) GO TO 125                                       00002980
C                                                                       00002986
C         IRTE .NF. 1  - FIRST STATION IN A SECTION (NOT REGION).       00002987
C         IRTE .EQ. 1  - LAST STATION IN PREVIOUS SECTION.              00002988
C                                                                       00002989
  100 IF (IRTE .NE. 1) GO TO 110                                        00002990
C                 LAST STATION - PREVIOUS BLOCK                         00003000
      IF (K .NE. 1 .OR. J .NE. 1) GO TO 102                             00003010
      MM = MM - 1                                                       00003020
      MMN = MMN - 1                                                     00003030
  102 IF(J .NE. 1) GO TO 103                                            00003031
      TTP(K) = (SCNTSI(K2) - P1ENT(KPJ)) /DEL2                          00003032
      MTP(K) = (SCMTSI(K2) - P1EMT(KPJ)) /DEL2                          00003033
      TFE(K)  =  P2ENT(KPJ)                                             00003034
      MFE(K)  =  P2EMT(KPJ)                                             00003035
  103 BP1KPJ = (SCB1(K2) - P1SCB1(KPJ)) /DEL2                           00003040
      DP1KPJ = (SCD1(K2) - P1SCD1(KPJ)) /DEL2                           00003050
      G13KPJ = (SCG13(K2) - P1SG13(KPJ)) /DEL2                          00003060
      GP1KPJ = (SCG1(K2) - P1SCG1(KPJ)) /DEL2                           00003070
C                                                                       00003080
  105 BP1KMJ = (SCB1(K5) - P2SCB1(KMJA)) /DEL2                          00003090
      DP1KMJ = (SCD1(K5) - P2SCD1(KMJA)) /DEL2                          00003100
      G13KMJ = (SCG13(K5) - P2SG13(KMJA)) /DFL2                         00003120
      GP1KMJ = (SCG1(K5) - P2SCG1(KMJA)) /DEL2                          00003130
      GO TO 120                                                         00003140
C                 FIRST STATION - NOT FIRST BLOCK                       00003190
  110 IF (K .NE. 1 .OR. J .NE. 1) GO TO 111                             00003200
```

```
      MM = MM + 1                                                       00003210
      MMN = MMN + 1                                                     00003220
  111 IF(J .NE. 1) GO TO 112                                            00003221
      TTP(K) = (SCNTSI(K1) - P2ENT(KPJ)) /DEL2                          00003222
      MTP(K) = (SCMTSI(K1) - P2EMT(KPJ)) /DEL2                          00003223
      TFE(K)  =  SCNTSI(K2)                                             00003224
      MFE(K)  =  SCNTSI(K2)                                             00003225
  112 BP1KPJ = (SCB1(K1) - P2SCB1(KPJ)) /DEL2                           00003230
      DP1KPJ = (SCD1(K1) - P2SCD1(KPJ)) /DEL2                           00003240
      G13KPJ = (SCG13(K1) - P2SG13(KPJ)) /DEL2                          00003250
      GP1KPJ = (SCG1(K1) - P2SCG1(KPJ)) /DEL2                           00003260
C                                                                       00003270
      BP1KMJ = (SCB1(K4) - P2SCB1(KMJA)) /DEL2                          00003280
      DP1KMJ = (SCD1(K4) - P2SCD1(KMJA)) /DEL2                          00003290
      G13KMJ = (SCG13(K4) - P2SG13(KMJA)) /DEL2                         00003300
      GP1KMJ = (SCG1(K4) - P2SCG1(KMJA)) /DEL2                          00003310
C                                                                       00003320
  120 BB1P    =  0.5   * (BP1KPJ +  FCTR *  BP1KMJ)                     00003330
      DD1P      = 0.5 * (DP1KPJ + FCTR * DP1KMJ)                        00003340
      GG13P = 0.5 * (FCTR * G13KMJ + FCTR2 * G13KPJ)                    00003350
      GG1P = 0.5 * (FCTR * GP1KMJ + FCTR2 * GP1KPJ)                     00003360
C                                                                       00003370
  125 IF (IRTE .NE. 1) GO TO 135                                        00003380
      TERM11 = P2SCB1(KPJ)                                              00003390
      TERM21 = P2SCD1(KPJ)                                              00003400
  130 BB1KJ    = 0.5 * (TERM11 + FCTR * P2SCB1(KMJA))                   00003410
      DD1KJ    = 0.5 * (TERM21 + FCTR * P2SCD1(KMJA))                   00003420
      DCM1KJ = 0.5 * (P2DCM1(KPJ) + FCTR * P2DCM1(KMJA))                00003430
      DCM2KJ = 0.5 * (FCTR * P2DCM1(KMJA) + FCTR2 * P2DCM1(KPJ))        00003440
      DCM4KJ = 0.5 * (P2DCM4(KPJ) + FCTR * P2DCM4(KMJA))                00003450
      DCM5KJ = 0.5 * (FCTR * P2DCM4(KMJA) + FCTR2 * P2DCM4(KPJ))        00003460
      DCK1KJ = 0.5 * (P2DCK1(KPJ) + FCTR * P2DCK1(KMJA))                00003470
      DCK2KJ = 0.5 * (FCTR * P2DCK2(KMJA)+ FCTR2 * P2DCK2(KPJ))         00003480
      DCK3KJ = 0.5 * (P2DCK3(KPJ) + FCTR * P2DCK3(KMJA))                00003490
      GG13KJ = 0.5 * (FCTR * P2SG13(KMJA) + FCTR2 * P2SG13(KPJ))        00003500
      GG1KJ = 0.5 * (FCTR * P2SCG1(KMJA) + FCTR2 * P2SCG1(KPJ))         00003510
      GO TO 150                                                         00003520
C                                                                       00003530
  135 BB1KJ  = 0.5 * (SCB1(K2) + FCTR * SCB1(K5))                       00003540
      DD1KJ  = 0.5 * (SCD1(K2) + FCTR * SCD1(K5))                       00003550
      DCM1KJ = 0.5 * ( DCM1(K2) + FCTR * DCM1(K5))                      00003560
      DCM2KJ = 0.5 * ( FCTR * DCM1(K5) + FCTR2 * DCM1(K2))              00003570
      DCM4KJ = 0.5 * ( DCM4(K2) + FCTR * DCM4(K5))                      00003580
```

```
      DCM5KJ = 0.5 * ( FCTR * DCM4(K5) + FCTR2 * DCM4(K2))                00003590
      DCK1KJ = 0.5 * ( DCK1(K2) + FCTR * DCK1(K5))                        00003600
      DCK2KJ = 0.5 * ( FCTR * DCK2(K5) + FCTR2 * DCK2(K2))                00003610
      DCK3KJ = 0.5 * (DCK3(K2) + FCTR * DCK3(K5))                         00003620
      GG13KJ = 0.5 * (FCTR * SCG13(K5) + FCTR2 * SCG13(K2))               00003630
      GG1KJ = 0.5 * (FCTR * SCG1(K5) + FCTR2 * SCG1(K2))                  00003640
C                                                                         00003650
  150 BB2KJ   =   BB1KJ                                                   00003670
      BB3KJ  =  POI  *  BB1KJ                                             00003680
      SS2  =  (1. - POI) / 2.                                             00003690
      GG2KJ = SS2 * BB1KJ                                                 00003700
      GG3KJ  =  GG1KJ                                                     00003710
      BB3P   =    POI   *  BB1P                                           00003720
      GG3P   = GG1P                                                       00003730
      GG2P   = SS2 * BB1P                                                 00003740
      DD2KJ    =    DD1KJ                                                 00003750
      DD3KJ  =  POI    *  DD1KJ                                           00003760
      DD3P   =  POI * DD1P                                                00003770
  152 TFETK   =  TFE(K)                                                   00003780
      TTHTK  =  TFE(K)                                                    00003790
      MFETK  =  MFE(K)                                                    00003800
      MTHTK  =  MFE(K)                                                    00003810
      TFETP  =  TTP(K)                                                    00003820
      MFETP  =  MTP(K)                                                    00003830
      IF(MMN .EQ. 0) GO TO 153                                            00003832
      PFEK   = PFE(K,MMN)                                                 00003840
      PTHK = PTH(K,MMN)                                                   00003850
      PNK = PN(K,MMN)                                                     00003860
      GO  TO  154                                                         00003861
C                                                                         00003862
  153 PFEK  =  PFE50(K)                                                   00003863
      PTHK  =  PTH50(K)                                                   00003864
      PNK   =  PN50(K)                                                    00003865
C                                                                         00003870
C             P AND X FORMULATION                                         00003880
C                                                                         00003890
C                                                                         00003900
  154 WTH = WTHX(MM)                                                      00003910
      WFE = WFEX(MM)                                                      00003920
      GAM = GAMA(MM)                                                      00003930
      RHO = RHOX(MM)                                                      00003940
      WFEP = WFEPX(MM)                                                    00003950
      LAM  =  HO /AO                                                      00003960
```

```
      LAM2  =  LAM * LAM                                                00003970
      IF (TCTR .GT. 1.0) GO TO 450                                      00003980
      IF (KPATH .EQ. 1) GO TO 450                                       00003990
      LAMO2  =  LAM /2.                                                 00004000
      LAM2O2  =  LAM * LAMO2                                            00004010
      LAM2O4  =  LAMO2 * LAMO2                                          00004020
      LAM2O8  =  LAM2O4 /2.                                             00004030
      GAM2  =  GAM **2                                                  00004050
      WTMWF  =  WTH - WFE                                               00004060
      WTMWF2  =  WTMWF **2                                              00004070
      WFWT  =  WFE * WTH                                                00004080
C                                                                       00004090
      IF (JPATH .EQ. 1) GO TO 400                                       00004100
      IF (IFLG .NE. 1) GO TO 235                                        00004110
      IF (I .NE. 1) GO TO 235                                           00004120
C                                                                       00004130
C                                          SET UP BOUNDARY MATRICES     00004139
  155 CALL RSLT (J,K,KK)                                                00004140
      IF (IRSFG .GT. 1)  GO TO 9998                                     00004150
      IF (IRSFG .EQ. 1)  GO TO 20                                       00004160
      RETURN                                                            00004170
C                                                                       00004180
  235 IF (I .NE. LLN)  GO TO 237                                        00004190
      IF (LN .EQ. N) GO TO 155                                          00004200
C                                                                       00004208
C                                  SET UP MATRICES IN EQUILIBRIUM EQ.   00004209
  237 CALL FGHPE (J,K,KK,IRTE)                                          00004210
      IF (IFGFG .GT. 1) GO TO 9998                                      00004220
      JPATH = 1                                                         00004230
      GO TO 23                                                          00004240
C                                                                       00004268
C                                SET UP L, M, N MATRICES USED IN G**    00004269
  400 CALL DYLMN (J,K,KK,IFDYN)                                         00004270
      IF (IFDYN .GT. 1) GO TO 9998                                      00004280
      KPATH = 1                                                         00004290
      GO TO 23                                                          00004300
C                                                                       00004308
C                                  FORM G**, D**, P AND X MATRICES      00004309
  450 CALL GMTX(J,K,KK,IFMX)                                            00004310
      IF (IFMX .GT. 1) GO TO 9998                                       00004320
      IF (TCTR .GT. 1.0) GO TO 20                                       00004330
      IF (IFGFG .EQ. 1) GO TO 20                                        00004340
      IRTE = 0                                                          00004350
      JPATH = 0                                                         00004360
      KPATH = 0                                                         00004370
      GO TO 23                                                          00004380
 9998 CONTINUE                                                          00004390
C                                                                       00004400
  340 FORMAT(1H-,14HENTERED PANDX. )                                    00004410
      RETURN                                                            00004420
      END                                                               00004430
```

3.12g RSLT Subroutine (BNDD)

```
$IBFTC BNDD                                                             00000010
C                                                                       00000019
      SUBROUTINE RSLT (J,K,KK)                                          00000020
C                                                                       00000030
C        COMPUTES THE BOUNDARY MATRICES FOR 'P AND X' MATRICES.         00000040
C                                                                       00000050
      DIMENSION    R(50,50), AA0(50,50), S(50,50), LI(50)              00000060
      DIMENSION  P(50,50), X(50), ZX(50)                               00000080
C                                                                       00000089
      COMMON  GDA(25), DEL, N, NNF, NTH,                                00000090
     1 BMTX(160), ICTR, KZTP, KZIP, KPTP, KPTR                          00000100
C                                                                       00000109
      COMMON /PXCMN/      MN, LLN, I, IFLG, LN, IPAFG, IFGFG,           00000110
     1 BB1KJ, BB2KJ, BB3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,   00000111
     2 GG13KJ, TFFIK, TTHIK, MFFIK, MTHIK, BB1P, BB3P, GG1P, GG2P,      00000112
     3 DD1P, DD3P, GG13P, TFFIP, MFFIP, OMG(5,5), ALM(5,5), LLI(5),     00000113
     4 WTH, WFF, GAM, RHO, WFFP, LAM, LAM2, LAM02, LAM202, LAM204,      00000114
     5 LAM208, GAM2, WTMWF, WTMWF2, WFW1, PIHK, PNK, PFFK, P, X,        00000115
     6 DCM1KJ, DCM2KJ, DCM3KJ, DCM4KJ, DCM5KJ, DCC1KJ, DCC2KJ, DCC3KJ,  00000118
     7 DCK1KJ, DCK2KJ, DCK3KJ                                           00000190
C                                                                       00000199
      COMMON /BLOCK1/  EMM2 (50,50)                                     00000200
      COMMON /BLOCK2/  EMM3 (50)                                        00000210
C                                                                       00000219
      EQUIVALENCE (GDA( 1),   A0),                (GDA( 2),   H0),      00000220
     1               (GDA( 3),   F0),             (GDA( 4), SIG0),      00000230
     2               (GDA( 5),  POI),             (GDA( 6),  ENF),      00000240
     3               (GDA( 7), BCIT),             (GDA( 8), BCIB),      00000250
     4               (GDA( 9),PFLAG),             (GDA(10), CEXT),      00000251
     5               (GDA(11), DFLT),             (GDA(12),  THT),      00000252
     6               (GDA(18),EPRNT)                                    00000253
C                                                                       00000260
      REAL   LAM, LAM02, LAM202, LAM204, LAM208, LAM2, KORO, KORO2,     00000270
     1           MFFIK, MTHIK, MFFIP, LI, LLI                           00000280
C      R, S, LT  MATRICES IN BOUNDARY EQUATIONS  (44, 45) SID 65-1633   00000290
C                                                                       00000300
      KK5  =  5 * NNF                                                   00000310
      IF (K .NE. 1)  GO TO 164                                          00000320
      IF (J .NE. 1)  GO TO 164                                          00000330
C                                               ZERO MATRIX ARRAYS      00000339
      DO 163 KN = 1,KK5                                                 00000340
      LT(KN) = 0.0                                                      00000350
      DO 162 JJ = 1,KK5                                                 00000360
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
      S(KN,JJ)   = 0.0                                                  00000370
      R(KN,JJ)   = 0.0                                                  00000380
  162 CONTINUF                                                          00000390
  163 CONTINUF                                                          00000400
C                                                                       00000409
  164 KORO = FLOAT(K-1) / RHO                                           00000410
      KORO2  =  KORO * KORO                                             00000420
      R(5*K-4,5*J-4)= BB1KJ * OMG(1,1)                                  00000430
      R(5*K-3,5*J-3)= GG1KJ /2. + LAM208 * WTMWF2 * GG13KJ              00000450
      R(5*K-3,5*J) =  LAM204 * WTMWF * GG13KJ                           00000470
      R(5*K-2,5*J-2)= GG2KJ * OMG(3,3)                                  00000480
      R(5*K-1,5*J-1)=  DD1KJ                                            00000500
      R(5*K, 5*J-3) =  ((GG13KJ * WTMWF /2.) * 0.5) * OMG(5,5)          00000510
      R(5*K,5*J)=  GG13KJ  *  0.5  * OMG(5,5)                           00000530
      R(5*K-4,5*J-3)   =  R(5*K-3,5*J-3)   *   OMG(1,2)                 00000540
      R(5*K-4,5*J)   =  R(5*K-3,5*J)   *   OMG(1,2)                     00000550
      R(5*K,5*J-1)   =  R(5*K-1,5*J-1) * OMG(5,4)                       00000570
C                                                                       00000579
      S(5*K-4,5*J-4)=  GAM *  BB3KJ                                     00000580
      S(5*K-4,5*J-3)=  KORO  *  BB3KJ                                   00000590
      S(5*K-4,5*J-2)=  WFE  *  BB1KJ  +  WTH  *  BB3KJ                  00000600
      S(5*K-3,5*J-4)=  LAM208  *  WTMWF2  *  GG13KJ  -  GG1KJ /2.       00000630
      S(5*K-3,5*J-3) = GAM * S(5*K-3,5*J-4)                             00000640
      S(5*K-3,5*J)   =  -GAM * R(5*K-3,5*J)                             00000650
      S(5*K-3,5*J-4)   =  KORO * S(5*K-3,5*J-4)                         00000660
      S(5*K-3,5*J-1)   =  -KORO * R(5*K-3,5*J)                          00000670
      S(5*K-2,5*J-4)= - WFE  *  GG2KJ * OMG(3,3)                        00000680
      S(5*K-2,5*J-1)=  GG2KJ * OMG(3,3)                                 00000690
      S(5*K-1,5*J-1)=  GAM  *  DD3KJ                                    00000730
      S(5*K-1,5*J)=  KORO  *  DD3KJ                                     00000740
      S(5*K, 5*J-4)  =  GG13KJ * WTMWF  /4.                             00000750
      S(5*K,5*J-3) = GAM * S(5*K, 5*J-4)                                00000760
      S(5*K,5*J-4)   =  KORO * S(5*K,5*J-4)                             00000770
      S(5*K,5*J-1)=  - KORO  *  GG13KJ   /2.                            00000780
      S(5*K,5*J)=  - GAM  *  GG13KJ /2.                                 00000790
      R(5*K-3,5*J-3) =  R(5*K-3,5*J-3) * OMG(2,2)                       00000800
      R(5*K-3,5*J) =  R(5*K-3,5*J)   * OMG(2,2)                         00000810
      R(5*K-1,5*J-1) =  R(5*K-1,5*J-1) * OMG(4,4)                       00000830
C                                                                       00000840
      S(5*K-4,5*J-4) = S(5*K-4,5*J-4) * OMG(1,1) + S(5*K-3,5*J-4)  *    00000850
     1 OMG(1,2)                                                         00000860
      S(5*K-4,5*J-3) = S(5*K-4,5*J-3) * OMG(1,1) + S(5*K-3,5*J-3) *     00000870
     1OMG(1,2)                                                          00000880
```

```
      S(5*K-4,5*J-2) = S(5*K-4,5*J-2) * OMG(1,1)                        000009[illegible]
      S(5*K-4,5*J-1) = S(5*K-4,5*J-1) * OMG(1,2)                        000009[illegible]
      S(5*K-4, 5*J)  = S(5*K-4, 5*J) * OMG(1,2)                         00000920
      S(5*K-3,5*J-3)=S(5*K-3,5*J-3) * OMG(2,2)                          00000940
      S(5*K-3,5*J) = S(5*K-3,5*J) * OMG(2,2)                            00000950
      S(5*K-3,5*J-4) = S(5*K-3,5*J-4) * OMG(2,2)                        00000960
      S(5*K-3,5*J-1) = S(5*K-3,5*J-1) * OMG(2,2)                        00000970
      S(5*K,5*J-4) = S(5*K,5*J-4) * OMG (5,5)                           00000980
      S(5*K,5*J-3) = S(5*K,5*J-3) * OMG(5,5)                            00001010
      S(5*K,5*J-1) = S(5*K,5*J-1) * OMG(5,5) + S(5*K-1,5*J-1)  *        00001060
     1 OMG(5,4)                                                         00001070
      S(5*K-1,5*J-1) = S(5*K-1,5*J-1) * OMG(4,4)                        00001080
      S(5*K,5*J)  = S(5*K,5*J) * OMG(5,5) + S(5*K-1,5*J) * OMG(5,4)     00001090
      S(5*K-1,5*J) = S(5*K-1,5*J) * OMG(4,4)                            000011[illegible]
C                                                                       000011[illegible]
      LT(5*K-4)    =    IFEIK    *   OMG(1,1) + LLI(1)                  00001110
      LT(5*K-3)   =   LLI(2)                                            00001120
      LT(5*K-2) = LLI(3)                                                00001130
      LT(5*K-1)    =    MFEIK    *   OMG(4,4) + LLI(4)                  00001140
      LT(5*K)   = LLI(5)                                                00001150
C                                                                       00001160
      IF (K .NE. J) GO TO 166                                           00001170
      S(5*K-2,5*J-2) = ALM(3,3)                                         00001180
      S(5*K-4,5*J-4) = S(5*K-4,5*J-4) + ALM(1,1)                        00001190
      S(5*K-3,5*J-3) = S(5*K-3,5*J-3) + ALM(2,2)                        00001200
      S(5*K-3,5*J-4) = S(5*K-3,5*J-4) + ALM(2,1)                        00001210
      S(5*K-1,5*J-1) = S(5*K-1,5*J-1) + ALM(4,4)                        00001230
      S(5*K-1,5*J) = S(5*K-1,5*J) + ALM(4,5)                            00001240
      S(5*K,5*J) = S(5*K,5*J) + ALM(5,5)                                00001250
C                                                                       00001260
  166 IF (K .NE. KK) GO TO 167                                          00001270
      IF (J .EQ.KK)  GO TO 169                                          00001280
  167 IRSFG = 10                                                        00001290
      GO  TO  180                                                       00001300
C                                                                       00001310
  169 IF (IFLG .GT. 1) GO  TO 305                                       00001320
      IF (L .GT. 1) GO TO 305                                           00001330
C                                                                       00001349
C                                              INITIAL BOUNDARY         00001350
      DO 175 K = 1,KK5                                                  00001360
      DO 175 J = 1,KK5                                                  00001370
  175 R(K,J)  =  (2./LFL) * R(K,J)                                      00001380
C                                                 SAVE  BO              00001389
```

```
      WRITE (11) R                                                      00001390
      DO 176 K = 1,KK5                                                  00001400
      DO 176 J = 1,KK5                                                  00001410
  176 AA0(K,J) = -.25 * R(K,J)                                          00001420
C                                                    SAVE   A0          00001429
      WRITE (11) AA0                                                    00001430
      DO 177 K = 1,KK5                                                  00001440
      DO 177 J = 1,KK5                                                  00001450
  177 FMM2(K,J) = 3. * AA0(K,J)                                         00001460
      CALL MAD (KK5,KK5, S, FMM2, S )                                   00001470
C                                                    SAVE   C0          00001479
      WRITE (11)  S                                                     00001480
C                                                    SAVE   G0          00001489
      WRITE (11) LT                                                     00001490
      END FILE 11                                                       00001500
      IRSFG = 1                                                         00001510
  180 IF(PFLAG .EQ. -1.E+10)  WRITE(6,310)                              00001520
      RETURN                                                            00001530
C                                                                       00001540
C                                                   TERMINAL BOUNDARY   00001550
  305 DO 306 K = 1,KK5                                                  00001560
      DO 306 J = 1,KK5                                                  00001570
  306 R(K,J) =  (3./(2.*DEL))  * R(K,J)                                 00001580
      CALL MAD (KK5,KK5,  S, R, AA0 )                                   00001590
      DO 307 K = 1,KK5                                                  00001600
      DO 307 J = 1,KK5                                                  00001610
      R(K,J) =  R(K,J) /3.                                              00001620
  307 S(K,J) =  -4. * R(K,J)                                            00001630
C                                                                       00001640
C                                  SAVE CN, BN, AN, GN  (IN THAT ORDER) 00001649
      WRITE (10) R, S, AA0, LT                                          00001650
      BACKSPACE 10                                                      00001660
C                                                                       00001670
      IRSFG = 0                                                         00001680
      REWIND  13                                                        00001690
      END FILE  3                                                       00001700
      END FILE  9                                                       00001710
      REWIND  11                                                        00001720
C                                  MOVE B0, A0, C0, G0 FROM TP 11 TO 3  00001728
C                                              BY SEPARATE RECORDS      00001729
      READ (11) P                                                       00001730
      WRITE  ( 3) P                                                     00001740
      READ  (11)  P                                                     00001750
```

```
      WRITE ( 3) P                                                      00001760
      READ (11) P                                                       00001770
      WRITE ( 3) P                                                      00001780
      READ (11) X                                                       00001790
      WRITE ( 3) X                                                      00001800
      AF = FILE (11,1)                                                  00001810
      END FILE 3                                                        00001820
C                              MOVE CN, BN, AN, GN FROM TAPE 10 TO 3    00001839
      READ (10) P, EMM2, AA0, X                                         00001840
      WRITE ( 3) P, EMM2, AA0, X                                        00001850
C                              MOVE A1, B1, C1, G1 FROM TAPE 11 TO 3    00001859
      READ (11) P, EMM2, AA0, X                                         00001860
      WRITE ( 3) P, EMM2, AA0, X                                        00001870
      BACKSPACE  10                                                     00001880
      BACKSPACE  10                                                     00001890
      AF = FILE (11, 1)                                                 00001900
C                                 MOVE P(N-2), X(N-2) - TP 11 TO 3      00001919
      READ (11) P, X   ,                                                00001920
      WRITE ( 3) P, X                                                   00001930
C                                                                       00001937
C                         MOVE L, M, N - TP 13 TO 9 (2 FILES POSSIBLE)  00001938
C                                                                       00001939
      NM2 = (N - 2) * 3                                                 00001940
      DO 170 I = 1,NM2                                                  00001950
      IF (I .EQ. 147)  END FILE 9                                       00001960
      READ (13) P                                                       00001970
      WRITE ( 9)  P                                                     00001980
  170 CONTINUE                                                          00001990
      END FILE  9                                                       00002000
      GO  TO  180                                                       00002010
  310 FORMAT (1H-,11HLEFT BNDRY, )                                      00002020
      END                                                               00002030
```

3.12h FGHPE Subroutine (FGHDY)

```
$IBFTC FGHDY                                                          1
C                                                              00000010
      SUBROUTINE FGHPE (J,K,KK,IPTF)                           00000020
C                                                              00000021
      DIMENSION         S(5,5), F(5,5), G(5,5), H(5,5)         00000023
      DIMENSION  P(50,50), X(50)                               00000060
C                                                              00000069
      COMMON  GDA(25), DEL, N, NNF, NTH,                       00000070
     1 BMTX(160), ICTR, KZTR, KZIR, KPTZ, IPTR                 00000080
C                                                              00000090
      COMMON /PXCMN/     MM, LLN, I, IFLG, LN, IPGFG, IFGFG,   00000110
     1 BB1KJ, BB2KJ, BB3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,   00000111
     2 GG13KJ, TEFTK, TTHIK, MEFTK, MTHTK, BB1P, BB3P, GG1P, GG2P,      00000112
     3 DD1P, DD3P, GG13P, TEFTP, MEFTP, OMG(5,5), ALM(5,5), LLI(5),     00000113
     4 WTH, WFF, GAM, RHO, WFFP, LAM, LAM2, LAMO2, LAM2O2, LAM2O4,      00000114
     5 LAM2O8, GAM2, WTHWF, WTNWF2, WFWT, PTHK, PNK, PFFK, P, X,        00000115
     6 DCM1KJ, DCM2KJ, DCM3KJ, DCM4KJ, DCM5KJ, DCC1KJ, DCC2KJ, DCC3KJ,  00000116
     7 DCK1KJ, DCK2KJ, DCK3KJ                                  00000170
C                                                              00000179
      COMMON /BLOCK1/  EMM2 (50,50)                            00000180
      COMMON /BLOCK2/  EMM3 (50)                               00000190
C                                                              00000199
      EQUIVALENCE (GDA( 1),    A0),           (GDA( 2),   H0), 00000200
     1            (GDA( 3),    E0),           (GDA( 4), SIG0), 00000210
     2            (GDA( 5),  POI),            (GDA( 6),  ENF), 00000220
     3            (GDA( 7), BCIT),            (GDA( 8), BCIB), 00000230
     4            (GDA( 9),PFLAG),            (GDA(1 ), CEXT), 00000240
     5            (GDA(11), DELT),            (GDA(12),  THT), 00000241
     6            (GDA(18),EPRNT)                              00000242
C                                                              00000249
      REAL   LAM, LAMO2, LAM2O2, LAM2O4, LAM2O8, LAM2, KORO, KORO2,   00000250
     1          MEFTK, MTHTK, MEFTP, LT(50), LLI               00000260
C                                                              00000270
C      F, G, H, PE  MATRICES IN EQUILIBRIUM EQUATIONS (33) SID 65-1633  00000280
C                                                              00000290
      KK5  =   5 * NNF                                         00000300
      IF (K .NE. 1)  GO TO 164                                 00000310
      IF (J .NE. 1)  GO TO 164                                 00000320
C                                       ZERO MATRIX ARRAYS     00000329
      DO 163 KN = 1,KK5                                        00000330
      DO 162 JJ = 1,KK5                                        00000340
      F(KN,JJ)  =  0.0                                         00000350
      G(KN,JJ)  =  0.0                                         00000360
```

```
      H(KN,JJ)  =  0.0                                                  00000370
  162 CONTINUE                                                          00000380
  163 CONTINUE                                                          00000390
C                                                                       00000399
  164 KORO = FLOAT(K-1) /RHO                                            00000400
  168 KORO2 = KORO * KORO                                               00000410
C                                                                       00000419
C     F,G,H,PF   MATRICES IN EQUILIBRIUM EQUATIONS (33)   SID 65-1633   00000420
C                                                                       00000421
      DELT2 = DELT * DELT                                               00000430
      F(5*K-4,5*J-4)=  BB1KJ                                            00000440
      F(5*K-3,5*J-3) = GG1KJ/2. + LAM2O8 * WTMWF2* GG13KJ               00000450
      F(5*K-3,5*J) = LAM2O4 * WTMWF * GG13KJ                            00000460
      F(5*K-2,5*J-2)=  GG2KJ                                            00000470
      F(5*K-1,5*J-1)=  LAM2  *  DD1KJ                                   00000480
      F(5*K,5*J-3) = F(5*K-3,5*J)                                       00000490
      F(5*K,5*J)=  LAM2O2  *  GG13KJ                                    00000500
C                                                                       00000509
      G(5*K-4,5*J-4)=  BB1P  +  GAM  *  BB1KJ                           00000510
      G(5*K-4,5*J-3)=  KORO  * ( BB3KJ  +  GG1KJ  /2.  -  LAM2O8  *     00000520
     1 WTMWF2 *  GG13KJ  )                                              00000530
      G(5*K-4,5*J-2)=  WFE  * ( BB1KJ  +  GG2KJ  ) + WTH  *  BB3KJ      00000540
      G(5*K-4,5*J) = -KORO * LAM2O4 * WTMWF * GG13KJ                    00000550
      G(5*K-3,5*J-4) = - G(5*K-4,5*J-3)                                 00000560
      G(5*K-3,5*J-3) = GG1P/2. + LAM2O8 * (WTMWF2 * GG13P - GG13KJ      00000570
     2* ( WTMWF2  *  GAM  + 2. *  WFFP  *  WTMWF ) ) +  GG1KJ  * GAM /2.00000580
      G(5*K-3,5*J-1) = -KORO * LAM2O4 * WTMWF * GG13KJ                  00000590
      G(5*K-3,5*J) = LAM2O4 *                                           00000600
     1(  GG13P  *  WTMWF  -  GG13KJ  * (2. *  GAM  * WTMWF  + WFFP  ) ) 00000610
      G(5*K-2,5*J-4) = - G(5*K-4,5*J-2)                                 00000620
      G(5*K-2,5*J-2)=  GG2P  +  GAM  *  GG2KJ                           00000630
      G(5*K-2,5*J-1) = GG2KJ                                            00000640
      G(5*K-1,5*J-3) = - G(5*K-3,5*J-1)                                 00000650
  180 G(5*K-1,5*J-2) = - G(5*K-2,5*J-1)                                 00000660
      G(5*K-1,5*J-1)=  LAM2 * (  DD1P  +  GAM  *  DD1KJ  )              00000670
      G(5*K-1,5*J)=  KORO * ( LAM2  *  DD3KJ  +  LAM2O2  *  GG13KJ  )   00000680
      G(5*K,5*J-4) = - G(5*K-4,5*J)                                     00000690
      G(5*K,5*J-3) = LAM2O4 * (                                         00000700
     1 GG13P  * WTMWF +  GG13KJ  * ( 2. * GAM * WTMWF  - WFFP )  )      00000710
      G(5*K,5*J-1) = - G(5*K-1,5*J)                                     00000720
  183 G(5*K,5*J)= LAM2O2 * ( GG13P  +  GAM  *  GG13KJ  )                00000730
C                                                                       00000739
      H(5*K-4,5*J-4)=GAM * PB3P - WFWT * BB3KJ - GAM2 * BB2KJ - KORO2 * 00000740
```

```
    1(GG1KJ/2.0+ LAM208* WTMWF2*GG13KJ) -WFF**2 * GG2KJ - DCK1KJ          -00000750
    2 2.0 * DCM1KJ / DELT2 - 11.0 * DCC1KJ / ( 6.0 * DELT )                 00000760
     H(5*K-4,5*J-3)=  KORO * ( BB3P  -  GAM  *  BB2KJ  -  GAM /2. *         00000770
    1 GG1KJ - GAM * WTMWF2 * LAM208 * GG13KJ )                              00000780
     H(5*K-4,5*J-2)=  WFF *  BB1P  +  WTH * ( BB3P  -  GAM *  BB2KJ  )      00000790
    1 +  BB1KJ  * (  WFEP  +  GAM  *  WFF  )                                00000800
     H(5*K-4,5*J-1) = WFF * GG2KJ + KORO2 * (LAM204 * WTMWF * GG13KJ )      00000810
     H(5*K-4,5*J) = KORO * GAM * LAM204 * WTMWF * GG13KJ                    00000820
     H(5*K-3,5*J-4)= KORO * ( LAM208 * (  WTMWF2 * GG13P  - WTMWF  *        00000830
    1  GG13KJ  * ( 3. * GAM * WTMWF -  2. *  WFEP ) ) - GG1P /2. + GAM      00000840
    2 *   (-GG1KJ/2. - BB2KJ ) )                                            00000850
     H(5*K-3,5*J-3)=(WFWT - GAM2)/2.* GG1KJ - GAM/2. * GG1P - KORO2*        00000860
    1 BB2KJ - WTH **2 * GG3KJ + LAM208 *( GAM* WTMWF2 * GG13P -GG13KJ       00000870
    2 * (WTMWF2 * (WFWT + 3.*GAM2)+2.* WTMWF* GAM*WFEP)) -DCK2KJ            00000880
    3       - 2.0 * DCM2KJ / DELT2 - 11.0 * DCC2KJ / ( 6.0 * DELT )         00000890
190 H(5*K-3,5*J-2)=- KORO * ( WFF *  BB3KJ + WTH * (  BB2KJ  + GG3KJ))00000900
     H(5*K-3,5*J-1)= KORO * ( LAM204 * ( GAM * ( 2. * WTMWF  +  WFEP )*00000910
    1 GG13KJ - WTMWF * GG13P) )                                             00000920
     H(5*K-3,5*J) = WTH * GG3KJ +  LAM204 * WTMWF *                         00000930
    2 ( GG13KJ  * ( WFWT + 2. * GAM2 ) - GAM *  GG13P  ) + GAM * LAM20400000940
    3  *  WFEP  *  GG13KJ                                                   00000950
193 H(5*K-2,5*J-4)=-  GG2KJ * ( WFEP  + GAM * WFF ) - WFF * ( GAM *         00000960
    1 BB3KJ  +  GG2P ) - WTH *  GAM  * BB2KJ                                00000970
     H(5*K-2,5*J-3) = H(5*K-3,5*J-2)                                        00000980
     H(5*K-2,5*J-2)=-KORO2* GG3KJ - WFF**2* BB1KJ -WTH* (2.*WFF*            00000990
    1 BB3KJ + WTH * BB2KJ ); - DCK3KJ - 2.0 * DCM1KJ/ DELT2 - 11.0          00001000
    2 * DCC3KJ / ( 6.0 * DELT )                                             00001010
     H(5*K-2,5*J-1) = GG2P + GAM * GG2KJ                                    00001020
     H(5*K-2,5*J) = KORO * GG3KJ                                            00001030
     H(5*K-1,5*J-4) = H(5*K-4,5*J-1)                                        00001040
     H(5*K-1,5*J-3) = KORO * LAM204 * GAM * WTMWF * GG13KJ                  00001050
195 H(5*K-1,5*J-1)=LAM2 *(GAM *DD3P- WFWT* DD3KJ - KORO2/2.*GG13KJ -        00001060
    1GAM2* DD2KJ) - GG2KJ                  -2.0 * DCM4KJ / DELT2            00001070
     H(5*K-1,5*J)= LAM2 * KORO * (  DD3P - GAM * ( GG13KJ  /2. +            00001090
    1  DD2KJ  )  )                                                          00001100
     H(5*K,5*J-4)= KORO * ( LAM204 * ( WTMWF *  GG13P - WFEP *  GG13KJ 00001110
    1 ) )                                                                   00001120
     H(5*K,5*J-3) = LAM204 * (GAM * WTMWF * GG13P - GG13KJ * (GAM *WFEP00001130
    1 + WFWT * WTMWF) ) + WTH * GG3KJ                                       00001140
     H(5*K,5*J-2) = H(5*K-2,5*J)                                            00001150
198 H(5*K,5*J-1)=- KORO * ( LAM202 * ( GG13P + GAM *  GG13KJ ) + LAM2 00001160
    1 * GAM *  DD2KJ  )                                                     00001170
     H(5*K  ,5*J ) = LAM202 * ((WFWT  - GAM2)*GG13KJ -GAM* GG13P)           00001180
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
      1 -F2R02 * LAM2* DD2KJ - GG2KJ                   -2. * DCMS J / DELT2
C                                                   BE FORMED IN GMTX
C
      IF (K .NE. KK) GO TO 203
      IF (J .EQ. KK)  GO TO 208
  203 IFGFG = 10
      GO  TO  251
C
C                                                 FORM A, B, C MATRICES
C
  208 DO 210 K=1,KK5
      DO 210 J = 1,KK5
      F(K,J) = (2./DELT) * F(K,J) * DELT
      G(K,J) = DELT * G(K,J)
  210 H(K,J) = DELT * H(K,J)
      CALL MAD (KK5,KK5, F, G, EMM2 )
      CALL MSU (KK5,KK5, F, G,  G )
      DO 212 K = 1,KK5
      DO 212 J = 1,KK5
      H(K,J) =  2. * DELT * H(K,J)
  212 F(K,J) = - 2. * F(K,J)
      CALL MAD (KK5,KK5, F,  H,  H )
      DO 214 K = 1,KK5
      DO 214 J = 1,KK5
  214 F(K,J) = EMM2(K,J)
C
C
      IF (MM .NE. 2) GO TO 260
C
      CALL INVNNM (G, 50, KK5, IERR )
      IF (IERR .LE. 0) GO TO 320
C
C                            SAVE A1, B1, C1 - TO BE USED IN FORMING Z(0)
C
      WRITE (11) F, H, G
      BACKSPACE 11
      BACKSPACE 11
      WRITE (12) F, H, G
  250 IFGFG = 1
  251 IF(PFLAG .EQ. -1.E+10)  WRITE(6,252)
  252 FORMAT (1H-,11HLEFT EGMTX. )
      RETURN
C
```

```
  260 WRITE (12) F, H, G
      IF (I .NE. 1) GO TO 250
      IF (IRTF .NE. 1) GO TO 250
      IFGFG = 0
      GO  TO  251
  320 WRITE (6,325)  I
  325 FORMAT (1H-,9X,16HSINGULAR MATRIX.,9X,4HI = ,I4)
      CALL EXIT
      STOP
      END
```

3.12i DYLMN Subroutine (LMNDY)

```
$IBFTC LMNDY
C                                             [illegible]
C
      SUBROUTINE  DYLMN(J,K,KP,IFLDYN)
C
C
      DIMENSION  AL(50,50), AM(50,50), AN(50,50))
      DIMENSION  P(5,5), Y(5)
      EQUIVALENCE (GDA( 1),   A0),            (GDA( 2),  [illegible]),
     1            (GDA( 3),   [illegible]),   (GDA( 4),  [illegible]),
     2            (GDA( 5),  POI),            (GDA( 6),  ENF),
     3            (GDA( 7), BCI),             (GDA( 8), BCIB),
     4            (GDA( 9),PFLAG),            (GDA(1 ), [illegible]),
     5            (GDA(11), DFLT),            (GDA(12),  THT),
     6            (GDA(18),FPRNT)
C
      COMMON  GDA(25), DFL, N, NNF, MTH,
     1 RMTX(160), ICTR
C
      COMMON /PXCMN/   NM, ILN, I, IFLG, LN, IPSFG, IFGFG,
     1 RR1KJ, RR2KJ, RR3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,
     2 GG13KJ, TFFTK, TTHIK, MFFIK, MTHIK, BB1P, BB3P, GG1P, GG2P,
     3 DD1P, DD3P, GG13P, TFFIP, MFEIP, OMG(5,5), ALM(5,5), LLI(5),
     4 WTH, WFF, GAM, RHO, WFEP, LAM, LAM2, LAM02, LAM202, LAM204,
     5 LAM208, GAM2, WTMWF, WTMWF2, WFIL, PIHK, PNK, PFFK, M, X,
     6 DCM1KJ, DCM2KJ, DCM3KJ, DCM4KJ, DCM5KJ, DCC1KJ, DCC2KJ, DCC3KJ,
     7 DCK1KJ, DCK2KJ, DCK3KJ
C
      COMMON /BLOCK1/  EMM2 (50,50)
      COMMON /BLOCK2/  EMM3 (50)
C
      REAL   LAM, LAM02, LAM202, LAM204, LAM208, LAM2, KURO, KURO2,
     1          MFFIK, MTHIK, MFFIP,     LLI
C
C
      KK5= 5 * NNF
      IF (K .NE. 1) GO TO 164
      IF (J .NE. 1) GO TO 164
C                                                  ZERO MATRIX ARRAYS
      DO 163 KN = 1,KK5
      DO 162 JJ = 1,KK5
      AI(KN,JJ) = 0.0
      AM(KN,JJ) = 0.0
```

```
      AN(KN.JJ) = 0.0                                                   00000350
  162 CONTINUE                                                          00000360
  163 CONTINUE                                                          00000370
C                                                                       00000379
  164 DELD = DEL/DELT                                                   00000380
      AL(5*K-4.5*J-4) = -10. * DELD * DCM1KJ - 6.0*DEL*DCC1KJ           00000390
      AL(5*K-3.5*J-3) = -10.*DELD * DCM2KJ- 6.0*DEL*DCC2KJ              00000400
      AL(5*K-2.5*J-2) = -10.0 * DELD * DCM1KJ - 6.0 * DEL * DCC3KJ      00000410
      AL(5*K-1.5*J-1) = -10.0 * DELD * DCM4KJ - 6.0 * DEL * DCC3KJ      00000420
      AL(5*K.5*J) = -10. * DELD * DCM5KJ                                00000430
C                                                                       00000439
      AM(5*K-4.5*J-4) = 8.0* DELD * DCM1KJ + 3.0 * DEL*DCC1KJ           00000440
      AM(5*K-3.5*J-3) = 8.0*DELD * DCM2KJ+ 3.0* DEL*DCC2KJ              00000450
      AM(5*K-2.5*J-2)  = 8.0 * DELD * DCM1KJ + 2.0 * DEL * DCC3KJ       00000460
      AM(5*K-1.5*J-1) = 8.0 * DELD * DCM4KJ                             00000470
      AM(5*K.5*J) = 8.0* DELD * DCM5KJ                                  00000480
C                                                                       00000489
      AN(5*K-4.5*J-4) = -2.0* DELD * DCM1KJ - 2.0/3.0*DEL*DCC1KJ        00000490
      AN(5*K-3.5*J-3) = -2.0 * DELD * DCM2KJ - 2.0/3.0 * DEL* DCC2KJ    00000500
      AN(5*K-2.5*J-2) = -2.0 * DELD * DCM1KJ - 2.0 / 3.0 * DEL * DCC3KJ 00000510
      AN(5*K-1.5*J-1) = -2.0 * DELD * DCM4KJ                            00000520
      AN(5*K.5*J) = -2.0 * DELD * DCM5KJ                                00000530
C                                                                       00000540
      IF (K .NE. KK) GO TO 225                                          00000550
      IF (J .EQ. KK) GO TO 235                                          00000560
  225 IFDYN = 10                                                        00000570
      GO  TO  249                                                       00000580
C                              MATRICES ARE COMPLETE - SAVE ON TP 13    00000588
C                                                                       00000589
C                                                                       00000590
  235 IFDYN = 1                                                         00000600
      WRITE (13) AL                                                     00000610
      WRITE (13) AM                                                     00000620
      WRITE (13) AN                                                     00000630
      BACKSPACE  13                                                     00000640
      BACKSPACE  13                                                     00000650
      BACKSPACE  13                                                     00000660
  249 IF(PFLAG .EQ. -1.E+10)  WRITE(6.250)                              00000670
  250 FORMAT (1H-. 9HLEFT LMN. )                                        00000680
      RETURN                                                            00000690
      END                                                               00000700
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

3.12j GMTX Subroutine (GDYN)

```
$IBFTC GDYN                                                                00000010
C                                         FORM G**, B**, P AND X MATRICES  00000015
C                                                                          00000018
      SUBROUTINE  GMTX(J,K,KK,IFMX)                                        00000020
C                                                                          00000030
C                                                                          00000040
      DIMENSION  PE(50), AL(50,50), FMM4(50), A(50,50), B(50,50),          00000050
     1           C(50,50), P(50,50), X(50)                                 00000060
      DIMENSION  CONDI(150), ZP(50), ZPP(50), ZPPP(50)                     00000080
C                                                                          00000090
      EQUIVALENCE (CONDI(  1),  ZP),(CONDI( 51), ZPP),(CONDI(101),ZPPP)    00000100
C                                                                          00000109
      EQUIVALENCE (GDA( 1),    A0),               (GDA( 2),    H0),        00000110
     1            (GDA( 3),    E0),               (GDA( 4),  SIG0),        00000120
     2            (GDA( 5),   POI),               (GDA( 6),   ENF),        00000130
     3            (GDA( 7),  BCIT),               (GDA( 8),  BCIB),        00000140
     4            (GDA( 9),PFLAG),                (GDA(10),  CEXT),        00000150
     5            (GDA(11),  DELT),               (GDA(12),   THT),        00000151
     6            (GDA(18),FPRNT)                                          00000152
C                                                                          00000160
      COMMON  GDA(25),  DEL, N, NNF, NTH,                                  00000170
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                             00000180
C                                                                          00000190
      COMMON /PXCMN/      MM, LLN, I, IFLG, LN, IRSFG, IFGFG,              00000200
     1 BB1KJ, BB2KJ, BB3KJ, GG1KJ, GG2KJ, GG3KJ, DD1KJ, DD2KJ, DD3KJ,      00000201
     2 GG13KJ, TFETK, TTHTK, MFETK, MTHTK, BB1P, BB3P, GG1P, GG2P,         00000202
     3 DD1P, DD3P, GG13P, TFETP, MFETP, OMG(5,5), ALM(5,5), LLI(5),        00000203
     4 WTH, WFE, GAM, RHO, WFEP, LAM, LAM2, LAMO2, LAM2O2, LAM2O4,         00000204
     5 LAM2O8, GAM2, WTMWF, WTMWF2, WFWT, PTHK, PNK, PFEK, P, X,           00000205
     6 DCM1KJ, DCM2KJ, DCM3KJ, DCM4KJ, DCM5KJ, DCC1KJ, DCC2KJ, DCC3KJ,     00000270
     7 DCK1KJ, DCK2KJ, DCK3KJ                                              00000280
C                                                                          00000288
      COMMON /BLOCK1/  EMM2 (50,50)                                        00000290
      COMMON /BLOCK2/  EMM3(50)                                            00000300
C                                                                          00000308
      REAL    LAM, LAMO2, LAM2O2, LAM2O4, LAM2O8, LAM2, KORO, KORO2,       00000310
     1          MFETK, MTHTK, MFETP, LT, LLI                               00000320
C                                                                          00000330
      KK5 = 5 * NNF                                                        00000340
      IF (K .NE. 1) GO TO 20                                               00000350
      IF (J .NE. 1) GO TO 30                                               00000360
      DO 15  KN = 1,KK5                                                    00000370
      PE(KN) = 0.0                                                         00000380
```

```
   15 CONTINUE
   20 IF(TCTR .EQ. 1.) GO TO 22
      READ (4)   TMP1, TMP2, TMP3, TMP4, TMP5
      GO  TO  28
C
   22 KORO = FLOAT(K-1) /RHO
      TMP1  =  TFETP + GAM *(TFETK - TTHTK)
      TMP2  =  TTHTK * KORO
      TMP3  =  WFE * TFETK + WTH * TTHTK
      TMP4  =  LAM2 *(MFETP + GAM *(MFETK - MTHTK) )
      TMP5  =  KORO * LAM2 * MTHTK
      WRITE (4)  TMP1, TMP2, TMP3, TMP4, TMP5
C
C                PE MATRIX
C
   28 PE(5*K-4)  =  - PFEK + TMP1
      PE(5*K-3) =  - PTHK    -   TMP2
      PE(5*K-2)  =  - PNK  -  TMP3
      PE(5*K-1)  =  TMP4
      PE(5*K)   =   - TMP5
   30 IF (K .NE. KK) GO TO 35
      IF (J .EQ. KK) GO TO 40
   35 IFMX = 10
      GO  TO  519
C
   40 DO 50 KN = 1,KK5
      PE(KN) = 2. * DEL * DELT * PE(KN)
   50 CONTINUE
C
      IF (TCTR .GT. 1.0 .AND. MM .EQ. 2) GO TO 70
      IF (TCTR .GT. 1.0) GO TO 60
      DO 55 KN = 1,150
   55 CONDI(KN) = 0.0
      WRITE ( 8) ZP, ZPP, ZPPP
      GO TO 85
C
   60 IF (KZTR .EQ. 8) GO TO 66
      BACKSPACE  11
      BACKSPACE  11
      GO TO 80
C
   66 BACKSPACE  8
      BACKSPACE  8
```

```
      GO TO 80                                                          00000720
C                                                                       00000728
   70 AF = FILE (KZTR, 1)                                               00000730
      IF (KZTR .EQ. 8) GO TO 76                                         00000740
      BACKSPACE  11                                                     00000750
      GO TO 80                                                          00000760
C                                                                       00000768
   76 BACKSPACE  8                                                      00000770
C                                                                       00000778
   80 READ (KZTR) ZP, ZPP, ZPPP                                         00000780
C                                                                       00000790
   85 DELT2 = DELT * DELT                                               00000810
      IF (ICTR - 2.0) 90,212,215                                        00000820
   90 DO 95 K = 1,KK5                                                   00000830
      EMM3(K) = 2. * ZP(K)                                              00000840
      EMM4(K) = DELT2 * ZPP(K)                                          00000850
      ZPP(K) = EMM3(K) + EMM4(K)                                        00000860
      EMM4(K) = 6. * EMM4(K)                                            00000870
      ZPPP(K) = 6. * DELT * ZPPP(K)                                     00000880
      EMM3(K) = 9. * ZP(K)                                              00000890
      ZPPP(K) = EMM4(K) + ZPPP(K) + EMM3(K)                             00000900
   95 CONTINUE                                                          00000910
C                                                                       00000920
C                                                  READ L MATRIX        00000928
  150 READ (13) AL                                                      00000930
      CALL MMY (KK5,KK5,  1, AL, ZP, EMM3)                              00000940
C                                                  READ M MATRIX        00000948
      READ (13) EMM2                                                    00000950
      CALL MMY (KK5,KK5,  1, EMM2, ZPP, EMM4)                           00000960
      CALL MAD (KK5,  1, EMM4, EMM3, EMM3)                              00000970
C                                                                       00000980
      DO 170 K = 1,KK5                                                  00000990
      DO 170 J = 1,KK5                                                  00001000
      EMM2(K,J) = 0.33333333 * EMM2(K,J)                                00001010
      AL(K,J) = AL(K,J)/6.                                              00001020
  170 CONTINUE                                                          00001030
      CALL MAD (KK5,KK5, AL, EMM2, AL)                                  00001040
C                                                  READ N MATRIX        00001048
  180 READ (13) EMM2                                                    00001050
      CALL MMY (KK5,KK5,  1, EMM2, ZPPP, EMM4)                          00001060
      DO 190 K = 1,KK5                                                  00001070
      EMM3(K) = EMM3(K) + EMM4(K)                                       00001080
      PE(K) = PE(K) + EMM3(K)                                           00001090
```

```
  190 CONTINUE                                                           00001100
C                                                                        00001108
  208 BACKSPACE  12                                                      00001110
  209 DO 210 K = 1,KK5                                                   00001120
      DO 210 J = 1,KK5                                                   00001130
  210 EMM2(K,J) = 3.5 * EMM2(K,J)                                        00001140
      CALL MSU (KK5,KK5, EMM2, AL, AL)                                   00001150
      GO TO 225                                                          00001160
C                                                                        00001170
C                                                                        00001180
  212 DO 213 K = 1,KK5                                                   00001190
      ZPPP(K) = DELT2 * ZPPP(K)                                          00001200
      EMM3(K) = 2. * ZPP(K)                                              00001210
      ZP(K) = 8. * ZP(K)                                                 00001230
      ZPPP(K) = ZPPP(K) + EMM3(K) + ZP(K)                                00001240
      ZPP(K) = ZPP(K) + ZP(K)/3.0                                        00001250
      ZP(K) = ZP(K) /6.0                                                 00001260
  213 CONTINUE                                                           00001270
C                                                                        00001280
  215 READ ( 9) AL                                                       00001290
      CALL MMY (KK5,KK5,  1, AL, ZP, EMM3)                               00001300
      READ ( 9) EMM2                                                     00001310
      CALL MMY (KK5,KK5,  1, EMM2, ZPP, EMM4)                            00001320
      CALL MAD (KK5,  1, EMM4, EMM3, EMM3)                               00001330
      READ ( 9) EMM2                                                     00001340
      CALL MMY (KK5,KK5,  1, EMM2, ZPPP, EMM4)                           00001350
      DO 220 K = 1,KK5                                                   00001360
      EMM3(K) = EMM3(K) + EMM4(K)                                        00001370
      PE(K) = PE(K) + EMM3(K)                                            00001380
  220 CONTINUE                                                           00001390
C                                                                        00001400
C                  G DBLSTAR HAS BEEN GENERATED AND STORED IN  PE        00001410
C                                                                        00001420
C                                                                        00001430
  225 IF (TCTR .LE. 2.0)  GO TO 230                                      00001440
      READ (13) A, B, C                                                  00001450
      GO TO 250                                                          00001460
C                                                                        00001468
  230 READ (12) A, B, C                                                  00001470
C                                                   COMPUTE  B*C         00001488
      IF (TCTR .GT. 1.0) GO TO 250                                       00001490
      CALL MAD (KK5,KK5, B, AL, B)                                       00001500
C                                                                        00001510
```

```
C                                             P AND X ARE READY TO BE CREATED   00001528
  250 IF (MM .NE. 2) GO TO 400                                                  00001530
C                                                                               00001540
C                                               STATION NO. 2 - TOP BOUNDARY    00001548
      IF (TCTR - 2.0) 265,260,300                                               00001550
  260 AF = FILE (3,2)                                                           00001560*
      BACKSPACE  3                                                              00001570
      READ ( 3) EMM4                                                            00001580
      BACKSPACE 3                                                               00001590
      BACKSPACE 3                                                               00001600
      READ ( 3) AL                                                              00001610
      BACKSPACE 3                                                               00001620
      BACKSPACE 3                                                               00001630
C                                                                               00001640
      CALL MMY (KK5,KK5,KK5, AL, C, EMM2)                                       00001650
      CALL MMY (KK5, KK5, KK5, EMM2, A, AL)                                     00001660
C                                                                               00001668
      READ ( 3)  P                                                              00001670
      BACKSPACE 3                                                               00001680
      BACKSPACE 3                                                               00001690
      CALL MSU (KK5, KK5, P, AL, AL)                                            00001700
      CALL MMY (KK5, KK5,KK5, EMM2, B, P)                                       00001710
C                                                                               00001720
      READ ( 3)  B                                                              00001730
      CALL MSU (KK5, KK5, B, P, B)                                              00001740
      CALL MMY (KK5, KK5,  1, EMM2, PE, EMM3)                                   00001750
      CALL MSU (KK5,  1, EMM4, EMM3, EMM4)                                      00001760
      CALL INVNNM (B, 50, KK5, IERR)                                            00001770
      IF (IERR .LE. 0)  GO TO 320                                               00001780
C                                                                               00001789
C                                               INVERSE REPLACES B ON TAPE      00001798
      WRITE (13) A, B, C                                                        00001800
C                                                                               00001810
      CALL MMY (KK5, KK5, KK5, B, AL, P)                                        00001820
      CALL MMY (KK5, KK5,  1, B, EMM4, X)                                       00001830
      GO TO 500                                                                 00001840
C                                                                               00001850
C                                                            READ  G0           00001858
  265 READ (11) EMM4                                                            00001860**
      BACKSPACE 11                                                              00001870
      BACKSPACE 11                                                              00001880
C                                                            READ  C0           00001888
      READ (11) AL                                                              00001890
```

*BACKSPACE 3 WHEN NOT USING ALTI0

**265 BACKSPACE 11 - REMOVE STATEMENT NO. 265 FROM CARD 1860

```
      BACKSPACE 11                                                      00001900
      BACKSPACE 11                                                      00001910
      CALL MMY (KK5,KK5,KK5, AL, C, EMM2)                               00001920
      CALL MMY (KK5,KK5,KK5, EMM2, A, C)                                00001930
C                                                    READ  A0           00001938
      READ (11) AL                                                      00001940
      BACKSPACE 11                                                      00001950
      BACKSPACE 11                                                      00001960
      CALL MSU (KK5,KK5, AL, C, A)                                      00001970
      CALL MMY (KK5,KK5,KK5, EMM2, B, C)                                00001980
C                                                    READ  B0           00001988
      READ (11) AL                                                      00001990
  270 CALL MSU(KK5,KK5, AL, C, AL)                                      00002000
      CALL MMY (KK5,KK5,  1, EMM2, PE, EMM3)                            00002010
      CALL MSU (KK5,  1, EMM4, EMM3, EMM4)                              00002020
      CALL INVNNM (AL, 50, KK5, IERR)                                   00002030
      IF (IERR .LE. 0)  GO TO 320                                       00002040
  275 CALL MMY (KK5,KK5,KK5, AL, A, P)                                  00002050
      CALL MMY (KK5,KK5,  1, AL, EMM4, X)                               00002060
      GO TO 500                                                         00002070
C                                                                       00002080
  300 READ (KPTR) MM, P, X                                              00002090
C                                                                       00002098
      AF = FILE (3,2)                                                   00002100
      BACKSPACE  3                                                      00002110*
      READ ( 3) EMM4                                                    00002120
      BACKSPACE 3                                                       00002130
      BACKSPACE 3                                                       00002140
      READ ( 3) AL                                                      00002150
      BACKSPACE 3                                                       00002160
      BACKSPACE 3                                                       00002170
C                                                                       00002180
      CALL MMY (KK5,KK5,KK5, AL, C, EMM2)                               00002190
      CALL MMY (KK5,KK5,  1, EMM2, PE, EMM3)                            00002210
      CALL MSU (KK5,  1, EMM4, EMM3, EMM4)                              00002220
      CALL MMY (KK5,KK5,  1, B,  EMM4, X)                               00002240
      GO TO 500                                                         00002250
C                                                                       00002260
C                                       * *  COMPUTE P AND X  **        00002270
C                                                                       00002280
  400 IF (TCTR .GT. 2.0) GO TO 450                                      00002290
      CALL MMY (KK5,KK5,KK5, C, P, EMM2)                                00002300
      CALL MSU (KK5,KK5, B, EMM2, B)                                    00002310
```

*BACKSPACE 3 WHEN NOT USING ALTIØ

```
      CALL INVNNM (B, 50, KK5, IERR)
      IF (IERR .LE. 0) GO TO 320
C
      IF (TCTR .EQ. 1.0) GO TO 450
      WRITE (13) A, B, C
  450 CALL MMY(KK5,KK5,  1, C, X, EMM3)
      IF (TCTR .LE. 2.0) GO TO 460
      READ (KPTR) MM, P, X
  460 CALL MSU (KK5,  1, PE, EMM3, PE)
      CALL MMY (KK5,KK5,  1, B, PE, X)
C
      IF (TCTR .GT. 2.0) GO TO 480
      CALL MMY (KK5,KK5,KK5, B, A, P)
C
  480 IF (MM .NE. N-2) GO TO 500
      IF (TCTR .GT. 1.0) GO TO 500
      WRITE (11) P, X
      GO TO 510
C
  500 IF (MM .NE. 2) GO TO 510
      IF (TCTR .GT. 1.0) GO TO 504
      AF = FILE(11,1)
      READ (11) A, B, C
      BACKSPACE  11
      WRITE (11) A, B, C, PE
      END FILE  11
      GO TO 510
C
  504 AF = FILE (3,1)
      READ ( 3) A, B, C, EMM3
      READ ( 3) A, B, C, EMM3
      BACKSPACE  3
      WRITE ( 3) A, B, C, PE
C
  510 IF (TCTR .GT. 2.0) GO TO 514
      WRITE (10) MM, P, X
      GO TO 515
C
  514 WRITE (KPTW) MM, P, X
      IF (MM .EQ. N-1) GO TO 540
  515 IFMX = 1
  519 IF(PFLAG .EQ. -1.E+10)  WRITE(6,520)
  520 FORMAT (1H-,10HLEFT GDYN. )
```

```
      RETURN                                                            00002712
C                                                                       00002716
  540 IF (KPTW .EQ. 12) GO TO 550                                       00002720
      BACKSPACE  10                                                     00002730
      BACKSPACE  10                                                     00002740
      GO TO 515                                                         00002750
C                                                                       00002759
  550 BACKSPACE  12                                                     00002760
      RACKSPACF  1?                                                     00002770
      GO TO 515                                                         00002780
C                                                                       00002789
  320 WRITE (6,325) MM                                                  00002790
  325 FORMAT (1H-,9X,16HSINGULAR MATRIX.,9X,4HMM= ,I4)                  00002800
      CALL EXIT                                                         00002805
      STOP                                                              00002806
C                                                                       00002820
      END                                                               00002830
```

3.12k ZMTRX Subroutine (SLND)

```
$IBFTC SLND
C
C          SOLUTION MATRICES
C
      SUBROUTINE  ZMTRX
C
C
      DIMENSION  PX(50,5 ),  Z(5 ), ZA(5 ), AFII(5 ,5 ), BBII(5 ,5 ),
     1 CCII(50,50), GGII(5 ), Z(5 )
      DIMENSION ZX2(50),          BBO(5 ,5 ), GGO(5 )
      DIMENSION  ZP(5 ), ZPP(5 ), ZPPP(5 ),             [illegible](1 )
C
      EQUIVALENCE  (GDA( 9),PFLAG),             (GDA(11),DELT)
C
      COMMON /BLK1/  EMM2   (50,50)
      COMMON /BLK2/  EMM3   (5 )
      COMMON  GDA(25), DEL, N, NNE, NIH,
     1 BMIX(16 ), ICIR, KZTR, KZIR, KPT , KPTW
C
      IF (KZTR .EQ. 8) GO TO   1
      BACKSPACE  11
      GO TO   2
    1 BACKSPACE  8
C
    2 DO  4  I = 1,50
    4 Z(I) = 0.0
C
      IF (ICIR .GT. 1.0)  GO TO 5
      AF = FILE (3,3)
      REWIND  11
      BACKSPACE  3                                                    *
C                             READ P AND X MATRICES FOR STA. (N-2)
      READ ( 3) BBO, GGO
      END FILE 3
      GO TO 10
C
    5 AF = FILE (3,2)
      IF (ICIR .GT. 2.0) GO TO 8
      BACKSPACE  10
      READ (10) I, BBO, GGO
      GO TO 10
    8 READ (KPTW) I, BBO, GGO
C
```

*BACKSPACE 3 WHEN NOT USING ALFIØ

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
   10 KK5 = 5 * NS1                                                   00000410
C                                                                     00000418
      DO 100 NN = 1,N                                                 00000420
      MN = N - NN + 1                                                 00000430
C                                                                     00000438
      IF (NN .NE. 1) GO TO 20                                         00000440
C                                                 LAST STATION        00000449
      IF (TCTR .GT. 2.0) GO TO 12                                     00000450
C                                                                     00000458
      READ (10) I, PX, XX                                             00000460
      GO TO 13                                                        00000470
C                                                                     00000478
   12 READ (KPTW) I, PX, XX                                           00000480
C                                                                     00000488
   13 IF (TCTR .GT. 1.0) GO TO 14                                     00000490
      READ (10) AAI1, BBI1, CCI1, GGI1                                00000500
      GO TO 16                                                        00000510
C                                                                     00000518
   14 READ ( 3) AAI1, BBI1, CCI1, GGI1                                00000520
      AF = FILE (3,1)                                                 00000530
C                                                                     00000538
   16 CALL MMMY (KK5,KK5,KK5, AAI1, EB, EMM2 )                        00000540
      CALL MMSU(KK5, KK5, EMM2, BBI1, BBI1 )                          00000550
      CALL MMMY(KK5, KK5,  1, AAI1, GG, EMM3 )                        00000560
      CALL MMSU(KK5,    1, GGI1, EMM3, GGI1 )                         00000570
      CALL MMMY(KK5, KK5,  1, BBI1, XX, EMM3 )                        00000580
      CALL MMAD(KK5,   1, GGI1, EMM3, GGI1 )                          00000590
      CALL MMMY(KK5, KK5, KK5, BBI1, PX, EMM2 )                       00000600
      CALL MMAD(KK5, KK5, CCI1, EMM2, CCI1 )                          00000610
      CALL INVMS  (CCI1, 5 , KK5, IERR )                              00000620
      IF (IERR .LE. 0) GO TO 120                                      00000630
      CALL MMMY(KK5, KK5,  1, CCI1, GGI1, ZX )                        00000640
C                                                                     00000648
      WRITE ( 3) MN, ZX                                               00000650
C                                                                     00000658
      WRITE (6,130)  MN, (ZX(KP), KP=1,KK5)                           00000660
      GO TO 100                                                       00000670
C                                                                     00000680
   20 IF (NN .EQ. N) GO TO 40                                         00000690
      IF (TCTR .GT. 2.0) GO TO 22                                     00000700
      IF (TCTR .EQ. 2.0 .AND. NN .EQ. 2)  GO TO  21                   00000710
      BACKSPACE 10                                                    00000720
   21 BACKSPACE  10                                                   00000730
```

```
C                                                                      00000738
      READ (10) 1, PX, XX                                              00000740
C                                                                      00000748
      GO TO 25                                                         00000750
C                                                                      00000758
   22 IF (KPTW .EQ. 10) GO TO  23                                      00000760
      IF (NN .NE. 2)  BACKSPACE  12                                    00000770
      BACKSPACE  12                                                    00000780
      GO TO  24                                                        00000790
C                                                                      00000798
   23 IF (NN .NE. 2)  BACKSPACE 10                                     00000800
      BACKSPACE  10                                                    00000810
   24 READ (KPTW) 1, PX, XX                                            00000820
   25 READ (KZIR) ZP, ZPP, ZPPP                                        00000830
C                                                                      00000840
      IF (TCT2 .NE. 1.0) GO TO 27                                      00000850
      IF (KZIR .EQ. 8) GO TO  26                                       00000860
      BACKSPACE 11                                                     00000870
      BACKSPACE 11                                                     00000880
      GO TO 27                                                         00000890
C                                                                      00000898
   26 BACKSPACE  8                                                     00000900
      BACKSPACE  8                                                     00000910
   27 CALL MMMY (KK5,KK5,  1, PX, ZY, Z)                               00000920
      CALL MMSU (KK5, 1, XX, Z, Z )                                    00000930
C                                                                      00000940
      IF (NN .NE. N-2) GO TO 30                                        00000950
      DO 28 K = 1,KK5                                                  00000960
   28 ZX2(K) = Z(K)                                                    00000970
C                                                                      00000978
   30 DO 35 K = 1,KK5                                                  00000980
   35 ZX(K) = Z(K)                                                     00000990
C                                                                      00000998
      WRITE  (KZTW)  ZX, ZP, ZPP                                       00001000
C                                                                      00001008
      WRITE ( 3) MN, ZX                                                00001010
C                                                                      00001018
      WRITE (6, 140) MN,  (ZX(IX), IX=1,KK5)                           00001020
C                                                                      00001028
      GO TO 100                                                        00001030
C                                                        FIRST STATION 00001040
   40 END FILE  3                                                      00001050
      REWIND  3                                                        00001060
```

```
      AF = FILE (3,2)                                                   00001070
      READ ( 3) AAI1, BBI1, CCI1, GGI1                                  00001080
C                                           A, B, C-1, G FOR 2ND STA.   00001089
      READ ( 3) AAI1, BBI1, CCI1, GGI1                                  00001090
      AF = FILE (3,2)                                                   00001100
C                                                                       00001110
      CALL MMMY(KK5,KK5,  1, BBI1, ZX, PZ )                             00001120
      CALL MMMY(KK5,KK5,  1, AAI1, ZX2, ZX )                            00001130
      CALL MMSU(KK5,  1, GGI1, ZX, GGI1 )                               00001140
      CALL MMSU(KK5,  1, GGI1, PX, GGI1 )                               00001150
      CALL MMMY(KK5,KK5,  1, CCI1, GGI1, Z )                            00001160
C                                                                       00001170
      WRITE (6, 140) MN, (Z(IX), IX=1,KK5)                              00001180
C                                            ZJ IN FILE BY ITSELF       00001189
      WRITE ( 3) MN, Z                                                  00001190
  100 CONTINUE                                                          00001200
C                                                                       00001210
C                                             COMPUTE VELOCITIES        00001220
      DO 102 I = 1,10                                                   00001230
  102 W(I) = 0.0                                                        00001240
C                                                                       00001250
      REWIND  3                                                         00001255
      REWIND KZTR                                                       00001260
      REWIND KZTW                                                       00001270
      DELT2 = DELT * DELT                                               00001280
C                                                                       00001290
      DO 108 I = 1,N                                                    00001300
      IF (I .EQ. 1 .OR. I .EQ. N) GO TO 108                             00001310
C                                                                       00001318
      READ (KZTW)  ZP,ZPP,ZPPP                                          00001320
C                                                                       00001328
      DO 104 NF = 1,NNF                                                 00001330
      NT = (NF - 1) * 5                                                 00001340
      NW = NT + 3                                                       00001350
      IF (TCTR .NE. 1.0) GO TO 103                                      00001360
      DD = ZPP(NW)                                                      00001370
      ZM1 = ZPPP(NW) *DELT2 + 2. * ZPP(NW) - ZP(NW)                     00001380
      W(NF) = (3.*ZP(NW) - 4.*DD + ZM1) / (2.*DELT)                     00001390
      GO TO 104                                                         00001400
  103 W(NF) = (3.*ZP(NW) - 4.*ZPP(NW) + ZPPP(NW)) / (2.*DELT)           00001410
  104 CONTINUE                                                          00001420
C                                                                       00001428
  106 WRITE (KZTR)  W                                                   00001430
```

```
C                                                                       00001438
  108 CONTINUE                                                          00001460
C                                                                       00001468
      END FILE KZTW                                                     00001470
C                                                                       00001478
      S1 = KZTR                                                         00001480
      KZTR = KZTW                                                       00001490
      KZTW = S1                                                         00001500
      S1 = KPTR                                                         00001510
      KPTR = KPTW                                                       00001520
      KPTW = S1                                                         00001530
      IF(PFLAG .EQ. -1.E+10)  WRITE(6,109)                              00001532
  109 FORMAT (1H-, 10HLEFT SOLTN )                                      00001533
C                                                                       00001538
  110 RETURN                                                            00001540
C                                                                       00001548
  120 WRITE (6,125)                                                     00001550
      CALL EXIT                                                         00001560
      STOP                                                              00001562
  125 FORMAT (1H-,10X,45HERROR -  INVERSION OF SINGULAR MATRIX IN 'Z', )00001570
C                                                                       00001580
  130 FORMAT (1H1,10X,24H'Z' MATRIX FOR STATION  , I4// (12X,1P5E17.7)) 00001590
  140 FORMAT (/// 10X,24H'Z' MATRIX FOR STATION  , I4// (12X,1P5E17.7)) 00001595
C                                                                       00001600
      END                                                               00001610
```

3.121 SUMS Subroutine (SUMD)

```
$IBFTC SUMD                                                             00000010
C             SOLUTION SUMMATION   W/O STRESSES            **           00000020
C                                                                       00000030
      SUBROUTINE SUMS                                                   00000040
C                                                                       00000041
C    NOMENCLATURE                                                       00000042
C     THT        HORIZONTAL ANGLES (DEGREES)  5 MAXIMUM                 00000043
C     FPRNT      FOURIER COMPONENT PRINT VALUES OF DEFLECTIONS AND      00000044
C                ROTATIONS   (3 POSSIBLE)                               00000045
C                                                                       00000050
      DIMENSION   Z(50), THT( 6), FPRNT( 3)                             00000060
      DIMENSION  ULZ(100,5), VLZ(100,5), WLZ(100,5), PHSLZ(100,5),      00000070
     1           PHTLZ(100,5), UL(100,5), VL(100,5), WL(100,5),         00000080
     2           PHSL(100,5), PHTL(100,5), WFEX(100), WTHX(100),        00000090
     3           GAMA(100), RHOX(100), WFEPX(100)                       00000100
C                                                                       00000110
      DIMENSION  B1(100,5), B2(100,5), B3(100,5), D1(100,5), D2(100,5), 00000150
     1           D3(100,5), G1(100,5), G2(100,5), G3(100,5), G13(100,5),00000151
     2           ENTSI(100,5), ENTTH(100,5), EMTSI(100,5), EMTTH(100,5) 00000152
C                                                                       00000160
      DIMENSION  ENFE( 5), ENTH( 5), ENFT( 5), QFE( 5), EMFE( 5),       00000170
     1           EMTH( 5), EMFT( 5), QTH( 5)                            00000180
C                                                                       00000190
      DIMENSION  COEFC(2200)                                            00000240
      DIMENSION  SCB1(100), SCB2(100), SCB3(100), SCG1(100), SCG2(100), 00000250
     1 SCG3(100), SCD1(100), SCD2(100), SCD3(100), SCG13(100),          00000251
     2 SCNTSI(100), SCNTTH(100), SCMTSI(100), SCMTTH(100), DCM1(100),   00000252
     3 DCM4(100), DCC1(100), DCC2(100), DCC3(100), DCK1(100), DCK2(100),00000253
     4 DCK3(100)                                                        00000254
C                                                                       00000309
      EQUIVALENCE (COEFC(   1),  SCB1),         (COEFC( 101),  SCB2), 00000310
     1            (COEFC( 201),  SCB3),         (COEFC( 301),  SCG1), 00000311
     2            (COEFC( 401),  SCG2),         (COEFC( 501),  SCG3), 00000312
     3            (COEFC( 601),  SCD1),         (COEFC( 701),  SCD2), 00000313
     4            (COEFC( 801),  SCD3),                                 00000314
     5 (COEFC( 901), SCG13), (COEFC(1001),SCNTSI), (COEFC(1101),SCNTTH),00000315
     6 (COEFC(1201),SCMTSI), (COEFC(1301),SCMTTH), (COEFC(1401),  DCM1),00000316
     7 (COEFC(1501),  DCM4), (COEFC(1601),  DCC1), (COEFC(1701),  DCC2),00000317
     8 (COEFC(1801),  DCC3), (COEFC(1901),  DCK1), (COEFC(2001),  DCK2),00000318
     9 (COEFC(2101),  DCK3)                                             00000319
C                                                                       00000390
      EQUIVALENCE (GDA( 1),   A0),           (GDA( 2),   H0),           00000400
     1            (GDA( 3),   E0),           (GDA( 4), SIG0),           00000410
```

```
     2             (GDA( 5),  POI),              (GDA( 6),  ENF),          00000420
     3             (GDA( 7), BCIT),              (GDA( 8), BCIB),          00000430
     4             (GDA( 9),PFLAG),              (GDA(10), CEXT),          00000431
     5             (GDA(11), DELT),              (GDA(12),  THT),          00000432
     6             (GDA(18),FPRNT)                                         00000433
C                                                                          00000510
      COMMON  GDA(25), DEL, N, NNF, NTH,                                   00000520
     1 BMTX(160), TCTR, KZTW, KZTR, KPTW, KPTR                             00000521
C                                                                          00000530
      REWIND   9                                                           00000540
C                                                                          00000600
      AF = FILE (3,3)                                                      00000610
      SS1 = SIGO/EO                                                        00000620
      SS2 = SS1 * AO                                                       00000630
C                                                                          00000639
      DO 200 I = 1,N                                                       00000640
      IF(I .EQ. 1)  WRITE( 6,246)                                          00000645
      II = N - I + 1                                                       00000650
      IF (I .EQ. N) AF = FILE (3,1)                                        00000655
C                                                                          00000660
      READ ( 3) MN, Z                                                      00000670
C                                                                          00000680
      WRITE (6,290) II                                                     00000690
C                                                                          00000700
      DO 35 IT = 1,5                                                       00000710
      B1(I,IT)  =  0.0                                                     00000720
      D1(I,IT)  =  0.0                                                     00000722
      ENTSI(I,IT)  =  0.0                                                  00000724
      EMTSI(I,IT)  =  0.0                                                  00000726
      ULZ(I,IT) = 0.0                                                      00000730
      VLZ(I,IT) = 0.0                                                      00000740
      WLZ(I,IT) = 0.0                                                      00000750
      PHSLZ(I,IT) = 0.0                                                    00000760
   35 THTLZ(I,IT) = 0.0                                                    00000770
C                                                                          00000780
      IT = 1                                                               00000790
   50 U = 0.0                                                              00000800
      V = 0.0                                                              00000810
      W = 0.0                                                              00000820
      PHS = 0.0                                                            00000830
      PHT = 0.0                                                            00000840
      IX = 1                                                               00000850
      THETA = THT(IT)                                                      00000860
```

```
C                                                                       00000870
      DO 150 NF = 1,NNF                                                 00000880
      ANF = NF - 1                                                      00000890
      NT = (NF - 1) * 5                                                 00000900
      NU = NT + 1                                                       00000910
      NV = NT + 2                                                       00000920
      NW = NU + 2                                                       00000930
      NFS = NV + 2                                                      00000940
      NFT = NW + 2                                                      00000950
      FCT = COSD (ANF * THETA)                                          00000960
      FCT2 = FCT * SS2                                                  00000970
      FCT1 = FCT * SS1                                                  00000980
      FCT3 = SIND (ANF * THETA)                                         00000990
      FCT4 = SS2 * FCT3                                                 00001000
      FCT5 = SS1 * FCT3                                                 00001010
C                                                                       00001020
      U = U + Z(NU) * FCT2                                              00001030
      V = V + Z(NV) * FCT4                                              00001040
      W = W + Z(NW) * FCT2                                              00001050
      PHS = PHS + Z(NFS) * FCT1                                         00001060
      PHT = PHT + Z(NFT) * FCT5                                         00001070
C                                                                       00001080
C                                   DERIVATIVES WITH RESPECT TO THETA 00001089
      ULZ(I,IT) = ULZ(I,IT) - Z(NU) * FCT4 * ANF                        00001090
      VLZ(I,IT) = VLZ(I,IT) + Z(NV) * FCT2 * ANF                        00001100
      WLZ(I,IT) = WLZ(I,IT) - Z(NW) * FCT4* ANF                         00001110
      PHSLZ(I,IT) = PHSLZ(I,IT ) - Z(NFS) * FCT5 * ANF                  00001120
      PHTLZ(I,IT) = PHTLZ(I,IT) + Z(NFT) * FCT1 * ANF                   00001130
C                                                                       00001140
      BNF = ANF + 1.                                                    00001150
      IF (BNF .NE. FPRNT(IX)) GO TO 150                                 00001160
C                                                                       00001170
      WRITE (6,300) THETA, ANF, U, V, W, PHS, PHT                       00001180
      IX = IX + 1                                                       00001190
  150 CONTINUE                                                          00001200
C                                                                       00001210
C                                          DISPLACEMENTS                00001229
      UL(I,IT) = U                                                      00001230
      VL(I,IT) = V                                                      00001240
      WL(I,IT) = W                                                      00001250
      PHSL(I,IT) = PHS                                                  00001260
      PHTL(I,IT) = PHT                                                  00001270
C                                                                       00001280
```

```
      IF (THT(IT+1) .LT. 0.0) GO TO 200
      IT = IT + 1
      GO TO 50
  200 CONTINUE
C
      REWIND 3
      IIT = IT
      S1 = E0 * H0
      S2 = S1 * H0 * H0
      S3 = (1. - POI)/2.
      S4 = SIGO * H0
      S5 = A0 /(S4 * H0 **2)
      II = 0
      NF2  =  2 * NNF
C
  210 READ ( 9) LN, IN, COEFC
      LLN = LN - IN + 1
      DO 240 I = 1,LLN
      II = II + 1
      K1 = NF2 * (I-1)
C
      DO 230 IT = 1,IIT
      THETA = THT(IT)
      DO 225 NF = 1,NF2
      ANF = NF - 1
      K2 = K1 + NF
      B1(II,IT) = B1(II,IT) + SCB1(K2) * COSD(ANF * THETA) * S1
      D1(II,IT) = D1(II,IT) + SCD1(K2) * COSD(ANF * THETA) * S2
      ENTSI(II,IT) = ENTSI(II,IT) + SCNTSI(K2) * COSD(ANF * THETA) * S4
      EMTSI(II,IT) = EMTSI(II,IT) + SCMTSI(K2) * COSD(ANF * THETA) * S5
  225 CONTINUE
      B11 = B1(II,IT)
      D11 = D1(II,IT)
      B2(II,IT) = B11
      B3(II,IT) = POI * B11
      D2(II,IT) = D11
      D3(II,IT) = POI * D11
      G1(II,IT) = S3 * B11
      G2(II,IT) = S3 * B11
      G3(II,IT) = B11 * S3
      G13(II,IT) = S3 * D11
      ENTTH(II,IT) = ENTSI(II,IT)
      EMTTH(II,IT) = EMTSI(II,IT)
```

```
 230 CONTINUE
 240 CONTINUE
C
     IF (LN .EQ. N) GO TO 245
     GO TO 210
C
 245 READ ( 3) WTHX, WFEX, GAMA, RHOX, WFEPX
C
     DNM = -2. * DEL
C
     DO 275 I = 1,N
     IF(I .EQ. 1)  WRITE( 6,246)
 246 FORMAT( 1H1 )
     L = N - I + 1
     H = L
     WFE = WFEX(L)
     WTH = WTHX(L)
     GAM = GAMA(L)
     RHO = RHOX(L)
     DRHO =  0.
     IF(RHO .NE. 0.)  DRHO = 1. /RHO
     DAO  =  1./AO
     DO 265 IT = 1,IIT
     THETA = THT(IT)
C                                         DERIVATIVES WITH RESPECT TO PSI
     IF (I .NE. 1) GO TO 250
C                                                       LAST STATION
     ULP = (4. * UL(I+1,IT) - 3. * UL(I,IT) - UL(I+2,IT) )/ DNM
     VLP = (4. * VL(I+1,IT) - 3. * VL(I,IT) - VL(I+2,IT) )/ DNM
     WLP = (4. * WL(I+1,IT) - 3. * WL(I,IT) - WL(I+2,IT) )/ DNM
     PHSLP = (4. * PHSL(I+1,IT) - 3. * PHSL(I,IT) - PHSL(I+2,IT) )/DNM
     PHTLP = (4. * PHTL(I+1,IT) - 3. * PHTL(I,IT) - PHTL(I+2,IT) )/DNM
     GO TO 260
 250 IF (I .EQ. N) GO TO 255
C                                        (NOTE - 'I' IS COUNTING BACKWARDS)
     ULP = (UL(I+1,IT) - UL(I-1,IT) ) /DNM
     VLP = (VL(I+1,IT) - VL(I-1,IT) ) /DNM
     WLP = (WL(I+1,IT) - WL(I-1,IT) ) /DNM
     PHSLP = (PHSL(I+1,IT) - PHSL(I-1,IT) ) /DNM
     PHTLP = (PHTL(I+1,IT) - PHTL(I-1,IT) ) /DNM
     GO TO 260
C                                                       FIRST STATION
 255 ULP = (UL(I-2,IT) + 3. * UL(I,IT) - 4. * UL(I-1,IT) ) /DNM
```

```
      VLP = (VL(I-2,IT) + 3. * VL(I,IT) - 4. * VL(I-1,IT) ) /DNM        00002130
      WLP = (WL(I-2,IT) + 3. * WL(I,IT) - 4. * WL(I-1,IT) ) /DNM        00002140
      PHSLP = (PHSL(I-2,IT) + 3. * PHSL(I,IT) - 4. * PHSL(I-1,IT) )/DNM 00002150
      PHTLP = (PHTL(I-2,IT) + 3. * PHTL(I,IT) - 4. * PHTL(I-1,IT) )/DNM 00002160
C                                                                       00002170
C                COMPUTATION OF STRAINS ** (STR 139, PG.17) **          00002180
C                                                                       00002190
  240 ESI = DAO * (ULP + WFE * WL(I,IT))                                00002200
      ETH = DAO * (DRHO * VLZ(I,IT) + GAM * UL(I,IT) + WTH * WL(I,IT))  00002210
      ESTH = DAO/2. * (DRHO * ULZ(I,IT) + VLP - GAM * VL(I,IT) )        00002220
      GSI = PHSL(I,IT) - DAO * (WFE * UL(I,IT) - WLP )                  00002230
      GTH = PHTL(I,IT) - DAO * (WTH * VL(I,IT) - DRHO * WLZ(I,IT) )     00002240
      EKSI = DAO * PHSLP                                                00002250
      EKTH = DAO * (DRHO * PHTLZ(I,IT) + GAM * PHSL(I,IT) )             00002260
      EKSTH = DAO/2. * (DRHO * PHSLZ(I,IT) + PHTLP - GAM * PHTL(I,IT) + 00002270
     1 DAO/2.* (WFE-WTH)*(DRHO* ULZ(I,IT) - VLP-GAM*VL(I,IT)))          00002271
      IF(PFLAG .EQ. -10.)  WRITE(6,261) L, THETA, ESI, ETH, ESTH, GSI,  00002280
     1                                  GTH, EKSI, EKTH, EKSTH          00002281
  261 FORMAT(/// 10X, 34HCHECKPRINT OF STRAINS AT STATION  ,I4,  5X,    00002265
     1  7HTHETA  ,1PE12.4// 8E13.4 )                                    00002286
C                                                                       00002290
C                COMPUTATION OF INTERNAL FORCES ** (STR 139, PG.12) **  00002300
C                                                                       00002310
      ENFE(IT)  =  B1(L,IT) * ESI + B3(L,IT) * ETH - ENTSI(L,IT)        00002320
      ENTH(IT)  =  B3(L,IT) * ESI + B2(L,IT) * ETH - ENTTH(L,IT)        00002350
      ENFT(IT)  =  G1(L,IT) * ESTH                                      00002360
      QFE(IT)   = G2(L,IT) * GSI                                        00002370
      EMFE(IT)  =  D1(L,IT) * EKSI + D3(L,IT) * EKTH - EMTSI(L,IT)      00002380
      EMTH(IT)  =  D3(L,IT) * EKSI + D2(L,IT) * EKTH - EMTTH(L,IT)      00002400
      EMFT(IT)  =  G13(L,IT) * EKSTH                                    00002420
      QTH(IT)    = G3(L,IT) * GTH                                       00002430
  265 CONTINUE                                                          00002710
C                                                                       00002720
      WRITE (6,268) L, (ENFE(J), ENTH(J), ENFT(J), QFE(J), J = 1,IIT)   00002730
      WRITE (6,270)  (EMFE(J), EMTH(J), EMFT(J), QTH(J), J = 1,IIT)     00002740
C                                                                       00002790
  268 FORMAT (1H-/11X,9HSTATION  ,I4// 19X, 5HN(XI),11X, 8HN(THETA), 7X,00002800
     1 11HN(XI,THETA),10X, 5HQ(XI) /(12X, 1P4E17.7) )                   00002810
C                                                                       00002820
  270 FORMAT (1H-,18X, 5HM(XI),11X, 8HM(THETA), 7X,11HM(XI,THETA), 8X,  00002830
     1 8HQ(THETA) / (12X, 1P4E17.7) )                                   00002840
C                                                                       00002880
  275 CONTINUE                                                          00002890
```

```
C                                                                       00002900
      IF(PFLAG .EQ. -1.F+10)  WRITE(6,280)                              00002902
  280 FORMAT (1H-, 9HLEFT SUMS )                                        00002906
      RETURN                                                            00002910
  290 FORMAT (////10X, 9HSTATION   ,I4)                                 00002920
  300 FORMAT (/// 10X, 9HTHETA   = ,F7.2//11X, 9HENF     = ,F5.1//21X,1HU,00002930
     1 16X,1HV,16X,1HW,12X, 7HPHI(X)), 9X,10HPHI(THETA) /(12X,1P5E17.7))00002940
C                                                                       00002950
      END                                                               00002960
```

```
                              * MEMORY MAP *

SYSTEM                                      00000 THRU  03765
FILE BLOCK ORIGIN                           03766
FILES          1.      UNIT06               (NO BUFF POOL ATTACHED)
               2.      UNIT01               (NO BUFF POOL ATTACHED)
               3.      UNIT02               (NO BUFF POOL ATTACHED)
               4.      UNIT03               (NO BUFF POOL ATTACHED)
               5.      UNIT04               (NO BUFF POOL ATTACHED)
               6.      UNIT05               (NO BUFF POOL ATTACHED)
               7.      UNIT07               (NO BUFF POOL ATTACHED)
               8.      UNIT08               (NO BUFF POOL ATTACHED)
               9.      UNIT09               (NO BUFF POOL ATTACHED)
              10.      UNIT10               (NO BUFF POOL ATTACHED)
              11.      UNIT11               (NO BUFF POOL ATTACHED)
              12.      UNIT12               (NO BUFF POOL ATTACHED)
              13.      UNIT13               (NO BUFF POOL ATTACHED)
              14.      UNIT14               (NO BUFF POOL ATTACHED)
              15.      UNIT15               (NO BUFF POOL ATTACHED)
              16.      UNIT16               (NO BUFF POOL ATTACHED)
PRE-EXECUTION INITIALIZATION                04266
CALL ON OBJECT PROGRAM                      04275
OBJECT PROGRAM                              04302 THRU  76606

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

  0  EXEC    04302      ///     /(76706)   EVEN     04303     ......  04577 *
     DECRD   04613       DECRD  (04613)
     NOFPT   04732      /FPSIGQ/ 04732      EVEN     04731
     .FPTRP  04733       EVEN    04743      FP.UND   05002 *   FP.OVR  05030 *   FP.DIV   05041 *
                         FP.ODD  05050 *   .FPOUT   05060 *   .FPARG  05070 *  /NOOVRQ/ 05121 *
                        /NOUNDQ/ 05122 *  /NODIVQ/  05123 *  /FPSIGQ/(04732)   FP.LOC   05124 *
                         OVFLOW  05125 *
     .LINK   05132      /.LDT  / 05132    /.LRECT/  05146    /.LVEC / 05174
     .LXCON  05222       .LXSTR  05222     .LXSTP   05227     .LXOUT  05324 *   .LXERR   05336
                         IBEXIT  05342 *   .LXRTN   05342     .LXCAL  05346     .DBCLS   05534 *
                         .LXARG  05655 *   .LO      05674    /TDUMPC/ 05676 *   .CLSE    05702 *
```

```
                  .LFBL    05703     .LUNB    05704 *   .DFOUT   05705     CTES..   05707 *
                  SC.SWT   05710     .OPNFQ   05711 *   .CLSFQ   05712     .WRTFQ   05713 *
                  .REDFQ   05714 *   CNTL..   05715
.LOVRY   05720    .LOVRY  (05720)    .LDT    (05132)    .LRECT  (05146)    .LVEC   (05174)
.LXSL    06472    .LXSEL   06472     .LXSCL   06473     .LXTST   06476     .LXOVL   06544
                  .LXRCT   06555 *   .LXIND   06714     .LXDIS   06722     .LXFLG   06723
                  .LTCH    06730
.ERAS.   06750    E.1      06750     E.2      06751     F.3      06752     E.4      06753
.XCC.    06754    CC.1     06754     CC.2     06755     CC.3     06756     CC.4     06757
XIT      06760    EXIT     06760     .EXIT.   06760
FXEM     06761    .FXEM.   06761     .FXOUT   07314 *   .FXARG   07322 *   /.OPTW./ 07376 *
FCNV     07410    .FCON.   07410     /HWDSQ / 07440 *   /NOHSHQ/ 07442 *   .FCNV.   07444
                  .ENDFS   07463     .CNVSW   07465     .FDX1    07471     .FDX2    07472
                  .DBC     07474     .DBC10   07632     .DBC20   07660     .DDSW    07670
                  .DDFIX   07677     .FIXSW   07705     .DDBC    07762     .DDRS1   10226
                  .DDRS2   10230 *   .D1      10233     .D2      10235     .FERR2   10322 *
                  .ANPT    10356     .DNPT    10373     .LNTP    10456     .AOUT    10525
                  .DFLT    10544     .FLT     10701     .DEXPN   10772     .FXD     10773
                  .HOUT    11136     .INTG    11207     .LOUT    11327     .OOUT    11350
                  .XCF     11402     .TEST    12126     .KOUNT   12131     .LIST    12134
                  .DONE    12145     .OUTBF   12212     EVEN     12211     .BUF     12242
                  .QSTO    12243     .WIDTH   12244     .GAIN    12245     .GAIN1   12246
                  .FBDBF   12256     EVEN     12267     .DDDFL   12303     .DDFLG   12304
                  .MQD     12305     .PEX     12306     .FEXP    12307     .DIG     12310
FIOB     12326    .FIOB.   12326     .FCNT    12431     .FBLT.   12527     .FBDT.   12547
                  .FRLR.   12573     .FRLR.  (12573)    .FWLR.   12637     .FWLR.  (12637)
                  .FBIP.   12677     .FRITE   12771
FIOH     12777    .FIOH.   12777     .FFIL.   13564     .FRTN.   13611
FIOS.    14007    ..FIOS   14007     ..FIDC   14067     ..FSEL   14124     ..FBCK   14142
                  ..FICK   14144     ..FCHK   14253
FRDD.    14504    ..FRDD   14504
FWRD.    14531    ..FWRD   14531
FBCD.    14557    ..FBCD   14557     ..FBCW   14561     ..FBCB   14572
FRDB.    14622    ..FRDB   14622
FWRB.    14651    ..FWRB   14651
FBIN.    15322    ..FBID   15322     ..FBIW   15324     ..FBIB   15337
FEFT.    15741    ..FEFT   15741
```

```
     FBST.    15760      ..FBST   15760
     FRWT.    16C42      ..FRWT   16042
     FVIO.    1607C      ..FVIO   16070
     UNIT06   16157      ..UN06   16157
     UN01     16160      .UN01.   16160
     UN02     16161      .UN02.   16161
     UN03     16162      .UN03.   16162
     UN04     16163      .UN04.   16163
     UN05     16164      .UN05.   16164
     UN07     16165      .UN07.   16165
     UN08     16166      .UN08.   16166
     UN09     16167      .UN09.   16167
     UN10     16170      .UN10.   16170
     UN11     16171      .UN11.   16171
     UN12     16172      .UN12.   16172
     UN13     16173      .UN13.   16173
     UN14     16174      .UN14.   16174
     UN15     16175      .UN15.   16175
     UN16     16176      .UN16.   16176
     FSCD     16177      COSD     16177      SIND     16201
     FSCN     16230      COS      16230      SIN      16231
     FSQR     16424      SQRT     16424
     FSLDI    16477      .FSLI.   16515      .FSDI.   16523 *
     FSLBI    16534      .FBLI.   16552      .FBDI.   16560 *
     FSLI     16572      .SLI.    16572      .SLI1.   16577      .SDI.    16605      .SDI1.   16613
     FSLDO    16626      .FSLO.   16644      .FSDO.   16652 *
     FSLBO    16663      .FBLO.   16701      .FBDO.   16707 *
     FSLO     16721      .SLO.    16721      .SLO2.   16727      .SDO.    16734      .SDO2.   16743
     FILE.O   16755      FILE     16756
     //       76706

1    DLKDY    17117      ///    /(76706)    DATLNK   17150
     DNTP     17164      EVFN     17165      DINTRP   17451 *
     CF3P     17510      EVEN     17511      CODIMA   20524
     ENTP     20652      EVEN     20653      ENTERP   21041

2    GMVD     21105      ///    /(76706)    GEOM     27137
```

3.13 PROGRAM NOMENCLATURE

Ⓐ

A0	a	Reference length
A0 (50, 50)	A_o	Boundary matrix, see Equation (1.46), Section 1.8
A1 (50, 50)		Another designation for A0 (50, 50)
ALF1		ENTRY to function subprogram TMP1, used to define the coefficient of thermal expansion for the stress calculations of layer one
ALF2		As ALF1, for layer two
ALM0 (5, 5)	$\bar{\Lambda}_o$	Boundary displacement matrix at the first meridional station, Equation (1.36), 0th harmonic
ALM1 (5, 5)		As ALM0 (5, 5) for the 1st harmonic
ALMN (5, 5)	$\bar{\Lambda}_N$	As ALM0 (5, 5) for the terminal boundary
ANX		Angle between the generator and axis of revolution; cone-cylinder option of GEOM.
AXL		Axial surface length

Ⓑ

B**		Modified B matrix for dynamic response, Equation (1.56), Section 1.9
B0 (50, 50)	B_o	Boundary matrix; see Equation (1.46), Section 1.8
B1 (50, 50)		Same as B0 (50, 50)
BBB		FUNCTION subprogram to define membrane stiffness, Equation (1.28).

BCD (36)		Three title cards read in executive program
BCIB		Boundary condition indicator for the terminal boundary; entered with the general data, GDA. See Section 2.8.
BCIT		As BCIB, for the initial boundary
BFCN		Deck name for the static version of subprogram, BBB
BMTX (160)		CØMMØN array which includes Ω, Λ and ℓ boundary matrices for the 0th and 1st harmonics
BN (50, 50)	B_N	Terminal boundary matrix; Equation (1.46), Section 1.8
BNDTB (17)		Special boundary array for station N read with the geometry data, GMDA. See Sections 1.8, 2.8.
BNDTX (17)		As BNDTB, for station one
Ⓒ		
C0, C1 (50, 50)	C_o	Boundary matrices; see Equation (1.46), Section 1.8.
CEXT		Number of time cycles desired. Read with GDA data, Section 3.3.2.
CN (50, 50)	C_N	Terminal boundary matrix, Equation (1.46), Section 1.8.
CØDIMA		Parabolic curve fitting subroutine, see Section 3.5.4.
CØEFC		Stiffness coefficient array set up in the DATLYR subroutine.
Ⓓ		
DATLD		Subroutine used to set up pressure loads

DATLNK		Sub-executive subroutine which monitors GEØM, DATLYR and DATLD
DATLYR		Subroutine which sets up the stiffness coefficient array, CØEFC
DBBDD		Deck name for the Dynamics version of subprogram BBB
DCC1, 2, 3	D_m	External damping coefficients found in the CØEFC array
DCK1, 2, 3	K_m	Spring coefficients, in CØEFC
DCM1, 4	M_m	Mass coefficients of translation and rotation, in CØEFC
DDD		ENTRY to function subprogram BBB, used to define the bending stiffness coefficients of the CØEFC array
DECRD		Data read subroutine; see Section 3.5.1
DEL	Δ	Interval size between meridional stations
DELT	δ	Time increment (seconds), read with GDA data. See Section 3.3.2.
DELTH		Interval size between circumferential stations. Constant = 2°.
DKDMP		Deck name for the Dynamics deck which sets up spring and damping coefficients of the array CØEFC
DKK1, 2, 3		FUNCTIØN and ENTRY points to the subprogram which sets up spring coefficient
DMASS		Deck name for Dynamics deck which forms the mass coefficients
DMM1, 4		FUNCTIØN and ENTRY points of deck DMASS

DMP1, 2, 3		ENTRY points to deck DKDMP to set up the translational damping coefficients
DN1		ENTRY point to function subprogram, EI1. Sets up distance from neutral axis of the first layer used in stress calculations.
DN2		As DN1 for the second stresses
DPRSS		Deck name for the Dynamics version of PPPN which supplies the pressure loadings
DTMP		Deck name for the Dynamics version of ENTT which gives the temperature load and moment
DYLMN		Subroutine subprogram in the Dynamics deck which sets up the L, M and N matrices of Equation (1.51), Section 1.9
Ⓔ		
E0	E_o	Reference Young's Modulus
EI1, 2		FUNCTIØN subprograms used to define the moduli of elasticity for the two layers at which stresses are desired
EM		Number of radii entered for the discrete point geometry option
EMTT		ENTRY point to subprogram ENTT; used to set up temperature moments
EN		Number of meridional stations
ENF		Number of Fourier harmonics where the first one is the 0th one
ENTH		Number of circumferential stations, internally set at ninety

ENTT		FUNCTIØN subprogram which sets the value of the temperature load, t_T, Equation (1.15), Section 1.6
Ⓕ		
F(50, 50)	F	Matrix of equilibrium Equation (1.34), Section 1.7
FGHPE		Subroutine which forms the F, G and H matrices of Equation (1.34). In the Statics version the force matrix PE is also set up here.
FPRNT		Fourier component print values, read with GDA data. See Section 3.3.2.
Ⓖ		
G (50, 50)	G	Matrix of equilibrium Equation (1.34), Section 1.7
G**	$g^*_{i,j}$	Modified g matrix for dynamic response, Equation (1.56), Section 1.9
GAMA	γ	ρ'/ρ
GDA		General data array, read by the executive program
GEØM		Geometry subroutine
GIN		Geometry indicator read with GMDA data; see Section 2.5
GMDA		The geometry data array; see Section 3.3.3
GMI		$\lvert GIN \rvert$
GMTX		Dynamics subroutine subprogram which modifies the B and g matrices and forms the P and X matrices of Equation (1.60), Section 1.10

H (50, 50)	H	Equilibrium matrix of Equation (1. 34), Section 1. 7
H0	h_o	Reference thickness
Ⓘ		
I		Station number within each block of stiffness coefficients, CØEFC, in PANDX subroutine
IFDYN		PANDX flag which determines when L, M and N matrices of the Dynamics routine have been completed
IFGFG		PANDX flag to determine entry into the FGHPE subroutine
IFLG		Stiffness coefficient block indicator; used in PANDX
IFMX		PANDX flag which shows whether the PE (force) matrix is complete
IRSFG		PANDX flag for boundary computations
IRTE		PANDX indicator for first or last station within a coefficient block
Ⓙ		
JPATH		Path indicator through the Fourier harmonic loop of PANDX; used to skip setting up the boundary conditions and the FGHPE subroutine
Ⓚ		
KFCN		Deck name for the Statics version of subprogram DKK1
KPATH		Path indicator through the Fourier harmonic loop of PANDX; used to skip boundary conditions and the DYLMN subroutine

KPTR, KPTW		Variable tape numbers 10 or 12 used in the Dynamics version for storing P and X matrices by subroutine GMTX
KZTR, KZTW		Variable tape number 8 or 11 used in GMTX for preserving the three previous solution matrices (Z) at each time interval

Ⓛ

L (50, 50)	L_i	Matrix used in the Dynamics version to modify the g matrix, Equation (1.51), Section 1.9
LL0 (5)	ℓ_o	Initial boundary, ℓ matrix; Equation (1.38), Section 1.7
LLLN (5)	ℓ_N	Terminal boundary, ℓ matrix

Ⓜ

M (50, 50)	M_i	As L (50, 50)
M (THETA)	M_θ	Bending moment per unit length in the circumferential direction
M (XI)	M_ξ	Bending moment per unit length in the meridional direction
M (XI, THETA)	$\overline{M}_{\xi\theta}$	Bending moment; shear
MFE		Current temperature moments at a given meridional station and for k harmonics
MM		Absolute station number in PANDX subroutine
MMN		Station number within block of loads in PANDX
MTP		First derivative of the temperature moments

Ⓝ

N		Fixed point form of EN, number of meridional stations
N (50, 50)	N_i	As L (50, 50)
N (THETA)	N_θ	Membrane force, circumferential
N (XI)	N_ξ	Membrane force, meridional
N (XI, THETA)	$\bar{N}_{\xi\theta}$	Membrane shear force
NNF	n	Fixed point form of ENF, number of Fourier harmonics
NTH		Fixed point form of ENTH, number of circumferential stations = 90

Ⓞ

ØMG0 (5, 5)	Ω_1	Boundary force matrix for the 0th harmonic; Equation (1.36), Section 1.7
ØMG1 (5, 5)	Ω_2	As ØMG0 (5, 5) for the 1st harmonic
ØMGN (5, 5)	Ω_3	As ØMG0 (5, 5) for the terminal boundary

Ⓟ

P (50, 50)	P	Matrix of Equation (1.60), Section 1.10
PANDX		Sub-executive subroutine which directs the formation of the various matrices needed in computing the P and X matrices of Equation (1.60), Section 1.10. This subroutine calls the RSLT, FGHPE, DYLMN and GMTX subroutines, the latter two in the Dynamics version only.
PE (50)	p	Force matrix of Equation (1.34), Section 1.7

PEL		Meridional distance to a station from the initial station
PFCN		Deck name for the Statics version of subroutine PPPN
PFE	p_ξ	Fourier component for load in the meridional direction
PFLAG		Print flag, read with GDA, general data. See Section 3.3.2.
PHI0	ϕ_o	Initial opening angle from vertical axis for sphere or toroid
PHIN	ϕ_N	Final opening angle from vertical axis for sphere or toroid
PHI (THETA)	Φ_θ	Rotation in the circumferential direction
PHI (XI)	Φ_ξ	Rotation in the meridional direction
PHS		Program name for PHI (XI)
PHT		Program name for PHI (THETA)
PN	p_ζ	Fourier component for load in the normal direction
PØI		Poisson's ratio
PØIS1		ENTRY point to function subprogram, EI1. Sets up Poisson's ratio for use in the stress calculations for the first layer.
PØIS2		As PØIS1 for the second stresses
PPPF		ENTRY point to function subprogram, PPPN. Defines the meridional pressure.
PPPH		As PPPF for circumferential pressure

PPPN		FUNCTIØN subprogram for pressure loadings. See Section 1.5 for sign convention.
PTH	p_θ	Fourier component for load in the circumferential direction

Ⓠ

Q (THETA)	Q_θ	Transverse force per unit length in the circumferential direction
Q (XI)	Q_ξ	Transverse force per unit length in the meridional direction

Ⓡ

R	r	Normal distance from axis to shell
R (50, 50)	R	Boundary matrix of Equation (1.46), Section 1.8
RA1		Radius of cone or cylinder at station 1
RC		Radius of curvature of sphere or toroid
RCURV		Input values of meridional radius of curvature
RCURZ		Input values of circumferential radius of curvature
RHØX	ρ	R/A0
RIPT		Discrete radii for general shell shape
RØFF		Offset distance of center of curvature from axis of revolution, for toroids
RSLT		Subroutine which computes the boundary matrices for the P and X matrices

Ⓢ

S (50, 50)	S	Boundary matrix of Equation (1.46), Section 1.8
SCB1, 2, 3	B_m	Membrane stiffness coefficients
SCD1, 2, 3	D_m	Bending stiffness coefficients
SCG1, 2, 3	G_m	Shear stiffness coefficients
SCG13	G_{13}	Shear twist stiffness coefficient
SCMTSI	$M^T_{\xi(n)}$	Meridional thermal moment coefficients
SCMTTH	$M^T_{\theta(n)}$	Circumferential thermal moment coefficients
SCNTSI	$t^T_{\xi(n)}$	Meridional thermal load coefficients
SCNTTH	$t^T_{\theta(n)}$	Circumferential thermal load coefficients
SIG0	σ_o	Reference stress
SIG (THETA)	σ_θ	Circumferential stress
SIG (THETA, ETA)	$\tau_{\theta\zeta}$	Circumferential transverse shear stress
SIG (XI)	σ_ξ	Meridional stress
SIG (XI. ETA)	$\tau_{\xi\zeta}$	Meridional transverse shear stress
SIG (XI, THETA)	$\sigma_{\xi\theta}$	In-plane shear stress
SUMS		Subroutine which does the Fourier summing for the deflections and rotations, computes the internal loads and, in the Static version, stresses

Ⓣ

TCTR		Time cycle number

TFCN		Deck name for the Statics version of function subprogram, ENTT
TFE		Current temperature load at a given meridional station and for k harmonics
THT		Circumferential angle THETA (degrees) at which print-outs of results are desired. (5 permitted)
TMP1, 2		FUNCTIØN subprograms used to define the temperature for the two layers at which stresses are desired
TTF1, 2		Deck names for function subprograms, TMP1 and TMP2, respectively
TTP		First derivative of the temperature loads
TU	t	Current time
Ⓤ		
U	u_ξ	Meridional displacement; see Figure 1.2
Ⓥ		
V	u_θ	Circumferential displacement; see Figure 1.2
Ⓦ		
W	w	Normal displacement; see Figure 1.2
W (THETA)	ω_θ	Circumferential curvature, print heading
W (XI)	ω_ξ	Meridional curvature, print heading
WDØT	$\frac{\partial w}{\partial t}$	Velocities
WFEPX	$\frac{\partial \omega_\xi}{\partial \xi}$	First derivative of meridional curvatures

WFEX	ω_{ξ}	Program name for W (XI)
WTHX	ω_{θ}	Program name for W (THETA)
Ⓧ		
X (50)	x	Matrix of Equation (1.62), Section 1.10
XI	ξ	Meridional distances to stations computed in GEOM
XIPT		Discrete XI distances or arc lengths array entered with GMDA
Ⓩ		
Z (50)	z	Solution matrix, Equation (1.38), Section 1.7
ZMTRX		Subroutine which solves for the Z matrix using the P and X matrices
ZP		Solutions for previous time cycle
ZPP, ZPPP		Solution matrices for the second and third previous cycles
ZTA	ζ	Circumferential distance to a station
ZX (50)		Another name for Z (50)