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POST-WRINKLING ANALYSIS OF HIGHLY PRESSURIZED CYLINDRICAL AND CONICAL SHELLS OF REVOLUTION SUBJECTED TO BENDING LOADS

VOLUME 1
THEORY AND COMPUTER PROGRAM DESCRIPTION

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FOREWORD

The work reported herein was carried out by TRW Systems for NASA Lewis Research Center under Contract No. NAS 3-8704. This work was administered under the direction of the Advanced Vehicles Branch of the Centaur Project Office, LeRc, with Mr. Ron Mancini as the technical monitor. The project manager for the contractor was Dr. G.A. Greenbaum of the Advanced Technology Department, Engineering Mechanics Laboratory.

This report is presented in two volumes. Volume I contains the derivation of the governing equations, and the description of the computer program. Volume II contains the computer program listing.

The authors of the two volumes are Dr. G.A. Greenbaum and Mr. D.C. Conroy. The authors wish to acknowledge contributions made by Drs. A. Kaplan, D.A. Evensen, D.J. Peery and Mr. Ron Mancini.

ABSTRACT

A theoretical analysis and computer program are developed to predict the elastic post-wrinkling behavior of highly pressurized cylindrical or conical shells of revolution subjected to bending loads. The computer program is written in a general manner, and may be used to solve many other geometrically nonlinear shell problems. The analysis is based on Sanders' nonlinear shell theory. The governing nonlinear partial differential equations are reduced to a system of ordinary first-order differential equations by expanding each variable in a Fourier series in the circumferential coordinate. These equations are reduced to a sequence of nonlinear finite difference equations which are solved by a modified Newton iteration method.

Numerical results, for a typical section of the Atlas missile, are presented and compared with experimental data. Correlation of analytical and experimental results are good and demonstrates the validity of the present analysis.

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NOMENCLATURE

$[a]$ . . . . . Matrix in equation (16)

$[A^*]$ . . . . . Matrix in equation (21)

$[a]$ . . . . . Matrix defined by equation (31)

$[C]$ . . . . . Support stiffness matrix, equation (28)

D . . . . . Extensional stiffness, equation (3)

d . . . . . Finite difference interval size

E . . . . . Young's modulus

e_r, e_y . . . . . Eccentricity between segments

e_r^s, e_y^s . . . . . Eccentricity of c.g. of support

$[K]$ . . . . . Matrix in equation (32)

K . . . . . Bending stiffness, equation (3)

L . . . . . Defined in equation (10)

$[L]$ . . . . . Matrix defined by equation (38)

M . . . . . Harmonic index

$M_\phi, M_\theta, M_{\phi\theta}$ . . . Bending and twisting moments

$N_\phi, N_\theta, N_{\phi\theta}$ . . . Inplane forces

$\overline{N}_{\phi\theta}$ . . . . . Defined by equation (2)

$\{P\}$ . . . . . Vector in equation (16)

$\{P^*\}$ . . . . . Vector in equation (21)

Q_ϕ, Q_θ . . . . . Transverse forces

$\overline{Q}_\phi$ . . . . . Defined by equation (2)

r . . . . . Normal distance from the axis of revolution to a point on the shell

s . . . . . Meridional coordinate

t . . . . . Thickness

$[U]$ . . . . . Upper triangular matrix, equation (37)

u . . . . . Circumferential displacement

v . . . . . Meridional displacement

w . . . . . Normal displacement

$\overline{X},\overline{Y},\overline{Z}$ . . . . . Surface loads, Figure 1.1

$\{Y\}$ . . . . . Vector of the fundamental variables

$\{\Delta Y\}$ . . . . . Correction to the fundamental variables

$\varepsilon_\phi,\varepsilon_\theta,\varepsilon_{\phi\theta}$ . . . Surface strains

$\overline{\varepsilon}_\phi,\overline{\varepsilon}_\theta$ . . . . . Linear portion of ε_ϕ and ε_θ

$\kappa_\phi,\kappa_\theta,\kappa_{\phi\theta}$ . . . Curvatures

λ . . . . . Nonlinear terms in equation (17)

μ . . . . . Poisson's ratio

$\omega,\omega_\phi,\omega_\theta$ . . . . Surface rotations

ϕ . . . . . Normal angle to the surface

θ . . . . . Circumferential angle

Subscripts

M . . . . . Harmonic index

n . . . . . Pivotal point

q . . . . . Segment number

Superscripts

s . . . . . Elastic support

q . . . . . Segment number

a . . . . . Applied discrete force

I. THEORY

1.1 Introduction

This report presents an analysis and a numerical method for determining the elastic post-wrinkling behavior of highly pressurized cylindrical and conical shells subject to axial compression and bending loads. It is well known that, for thin-walled pressurized cylinders subject to bending loads, the collapse load is considerably higher than the initial wrinkling load (Reference 1 and 2). Weingarten, et. al., (Reference 2), noted this result from their tests of mylar cylinders and cones; however, they pointed out that as the applied bending moment was increased, the depth of the wrinkles grew, and there was a possibility of fracturing the shell before the collapse load was attained. In practical pressure stabilized structures, such as the Atlas/Centaur vehicle, the presence of circumferential splice joints further increases the possibility of fracturing the cylinder. They form axisymmetric discontinuities and are the areas at which local wrinkling first occurs. Recent bending tests of the Atlas vehicle, (Reference 3), indicated that the Atlas could be loaded, without failure, well above the initial wrinkling load. These tests showed that as the bending moment was increased deep wrinkles and large stresses developed around the circumferential splice joints. Therefore, before pressure stabilized vehicles can be designed to achieve their full load-carrying capacity, a need existed to analytically determine their post-wrinkling behavior. The primary objective of the present investigation is to provide the designer and stress analyst an analytical technique for determining the post-wrinkling deformations, strains and stresses of Atlas/Centaur type structures.

In order to achieve the stated objective, a numerical analysis and a computer program were developed to determine the nonlinear behavior of nonsymmetrically loaded shells of revolution. Numerous authors have formulated numerical techniques to obtain the linear behavior of nonsymmetrically loaded shells of revolution, (e.g., see References 4, 5, and 6). Some

attention has been given to the nonlinear axisymmetric loaded shell of revolution problem, (e.g., see References 7, 8, and 9), however, the nonlinear asymmetric loaded shell of revolution has not received much attention. Famili and Archer, (Reference 10), developed a numerical method for obtaining the finite asymmetric deformations of shallow spherical shells. Their technique consists of using a double finite difference mesh, together with an iteration scheme, to determine the asymmetric post-buckling state for a spherical cap under uniform external pressure.

During the course of this investigation, the authors' attention was called to a recent report by Ball, (Reference 11). Ball uses a numerical technique similar to that presented here, but solves four second-order differential equations rather than the eight first-order equations as presented in this report. Ball also uses a different type of iteration technique than presented in this report. The authors found that Ball's technique did not converge for the post-wrinkling problem.

The field equations used in this report were derived by Sanders, (Reference 12), and are based on the assumptions of small strains and moderately small rotations. Following a method presented by Kalnins, (Reference 4), each of the variables is expanded in a Fourier series in the circumferential direction, and the field equations are reduced to eight nonlinear first-order differential equations. Unlike the linear theory, the equations for each harmonic do not uncouple when coefficients of like trigonometric arguments are collected together. The nonlinear terms involve products of series, hence the Fourier harmonics become coupled. The task of solving these equations in the coupled form would be an enormous undertaking because, for the solution of any practical problem, this would involve solving a very large band matrix many times. For this reason, a numerical technique was developed whereby the harmonics are solved in the uncoupled form. Briefly, the solution technique consists of reducing the eight first-order differential equations to a system of nonlinear algebraic equations by the use of the finite difference method. These equations are then solved by a modified Newton method. The modification of the Newton

method consists of retaining only the nonlinear terms on the left side of the equations which do not couple harmonics; all other nonlinear terms are placed on the right side of the equations. An iteration method is then used on trial solution vectors until the solution converges. Experience in using this method has indicated that, at least for the class of problems considered here, the convergence properties are quite good.

To illustrate the application of the method developed in this report, and to verify the analytical method, the post-wrinkling behavior of a portion of the Atlas vehicle was obtained. The analytical and experimental results are compared and found to be in close agreement.

1.2 Derivation of the Field Equations

1.2.1 Equations of Equilibrium

The equations of equilibrium for a shell of revolution bounded by two meridional planes and two parallel planes, Figure 1.1 are given in Reference 12, based on the assumptions of small strains and moderately small rotations. For a conical shell these equations reduce to

$$N_{\phi\theta}^{\bullet} + 2N_{\phi\theta}\frac{\cos\phi}{r} + \frac{N_{\theta}'}{r} + Q_{\theta}\frac{\sin\phi}{r} + \frac{1}{2r}\left(M_{\phi\theta}\frac{\sin\phi}{r}\right) - \frac{\sin\phi}{r}(N_{\phi\theta}\omega_{\theta} + N_{\theta}\omega_{\theta}) \tag{1a}$$

$$+ \frac{1}{2}[(N_{\phi} + N_{\theta})\omega]^{\bullet} + \bar{Z}\omega_{\phi} + \bar{X} = 0$$

$$N_{\phi}^{\bullet} + (N_{\phi} - N_{\theta})\frac{\cos\phi}{r} + \frac{N_{\phi\theta}'}{r} - \frac{1}{2}M_{\phi\theta}'\frac{\sin\phi}{r^2} - \frac{1}{2r}[(N_{\phi} + N_{\theta})\omega]' + \bar{Z}\omega_{\theta} + \bar{Y} = 0 \tag{1b}$$

$$Q_{\phi}^{\bullet} + Q_{\phi}\frac{\cos\phi}{r} + \frac{Q_{\theta}'}{r} - N_{\theta}\frac{\sin\phi}{r} - \frac{1}{r}[r(N_{\phi}\omega_{\theta} + N_{\phi\theta}\omega_{\phi})]^{\bullet} - \frac{1}{r}[N_{\phi\theta}\omega_{\theta} + N_{\theta}\omega_{\phi}]' \tag{1c}$$

$$+ \bar{Z}[(1 + \bar{\varepsilon}_{\phi} + \bar{\varepsilon}_{\phi})] = 0$$

$$M_{\phi}^{\bullet} + (M_{\phi} - M_{\theta})\frac{\cos\phi}{r} + \frac{M_{\phi\theta}'}{r} - Q_{\phi} = 0 \tag{1d}$$

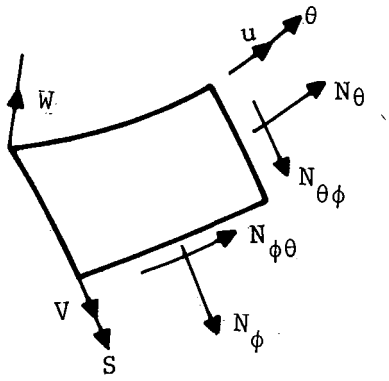
$$M_{\phi\theta}^{\bullet} + 2M_{\phi\theta}\frac{\cos\phi}{r} - Q_{\theta} = 0 \tag{1e}$$

where

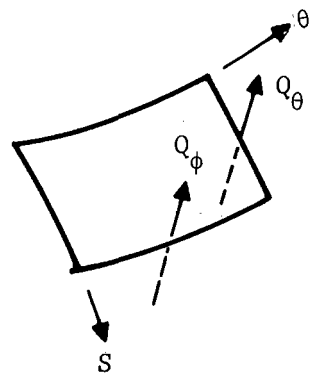
$$(\ )^{\bullet} = \frac{\partial}{\partial S} \qquad (\ )' = \frac{\partial}{\partial\theta}$$

The equilibrium equations (1) represent the sum of forces and moments acting along the tangents to the undeformed middle surface. The surface forces $\bar{X}$ and $\bar{Y}$ act in the direction of the tangents to the undeformed middle surface, but $\bar{Z}$ acts normal to the deformed middle surface.

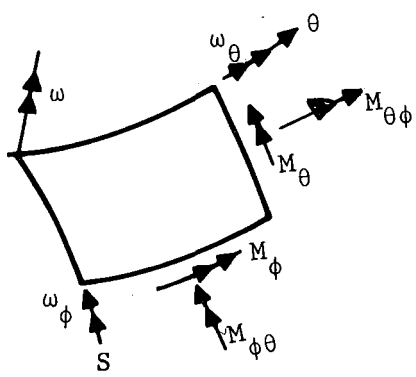
The boundary conditions considered on an edge, S = constant, are to prescribe



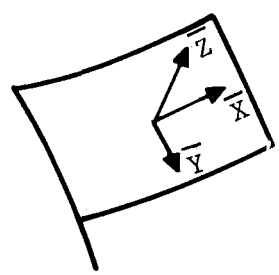
1.1(a) Membrane Forces and Displacements



1.1(b) Transverse Forces



1.1(c) Moments and Rotations



1.1(d) Surface Loads

Figure 1.1 Positive Direction of the Forces and Moments Acting on a Shell Element

$$N_\phi \quad \text{or} \quad v \tag{2a}$$

$$\overline{N}_{\phi\theta} = N_{\phi\theta} + \frac{3}{2} M_{\phi\theta} \frac{\sin\phi}{r} + \frac{1}{2}(N_\phi + N_\theta)\omega \quad \text{or} \quad u \tag{2b}$$

$$\overline{Q}_\phi = Q_\phi + \frac{M'_{\phi\theta}}{r} - (N_\phi \omega_\theta + N_{\phi\theta}\omega_\phi) \quad \text{or} \quad w \tag{2c}$$

$$M_\phi \quad \text{or} \quad \omega_\theta \tag{2d}$$

1.2.2 Constitutive Relations

The constitutive relations for an isotropic homogeneous shell are given by

$$N_\phi = D(\varepsilon_\phi + \mu\varepsilon_\theta) \tag{3a}$$

$$N_\theta = D(\varepsilon_\theta + \mu\varepsilon_\phi) \tag{3b}$$

$$N_{\phi\theta} = D(1 - \mu)\varepsilon_{\phi\theta} \tag{3c}$$

$$M_\phi = K(\kappa_\phi + \mu\kappa_\theta) \tag{3d}$$

$$M_\theta = K(\kappa_\theta + \mu\kappa_\theta) \tag{3e}$$

$$M_{\phi\theta} = K(1 - \mu)\kappa_{\phi\theta} \tag{3f}$$

where

$$D = \frac{Et}{1 - \mu^2}, \qquad K = \frac{Et^3}{12(1 - \mu^2)}$$

1.2.3 Strain-Displacement Relation

The strain displacement relations are given by

$$\varepsilon_\phi = v' + \frac{1}{2}\omega_\theta^2 + \frac{1}{2}\omega^2 \tag{4a}$$

$$\varepsilon_\theta = \frac{1}{r}(v\cos\phi + u' + w\sin\phi) + \frac{1}{2}\omega_\phi^2 + \frac{1}{2}\omega^2 \tag{4b}$$

$$\varepsilon_{\phi\theta} = \frac{1}{2}\left(u^{\cdot} + \frac{v'}{r} - u\,\frac{\cos\phi}{r} + \omega_{\phi}\omega_{\theta}\right) \tag{4c}$$

$$\kappa_{\phi} = \omega_{\theta}^{\cdot} \tag{4d}$$

$$\kappa_{\theta} = \frac{\omega_{\phi}'}{r} + \omega_{\theta}\,\frac{\cos\phi}{r} \tag{4e}$$

$$\kappa_{\phi\theta} = \frac{1}{2}\left(\omega_{\phi}^{\cdot} + \frac{\omega_{\theta}'}{r} - \omega_{\theta}\,\frac{\cos\phi}{r} + \omega\,\frac{\sin\phi}{r}\right) \tag{4f}$$

where rotations and displacements are related by the equations

$$\omega = \frac{1}{2}\left(u^{\cdot} + \frac{u\cos\phi}{r} - \frac{v'}{r}\right) \tag{5a}$$

$$\omega_{\theta} = w^{\cdot}$$

$$\omega_{\phi} = -\frac{1}{r}\,[w' - u\sin\phi] \tag{5c}$$

1.2.4 Reduction to Eight First-Order Differential Equations

Previous investigators, (Reference 6), and one of the present authors (Reference 13), have solved the linear shell of revolution equations by reducing the field equations to four second-order differential equations in terms of u, v, w and M_{ϕ}. In using this formulation it was found that in certain classes of problems, (specifically, problems involving large inextensional deformations), numerical inaccuracies occurred due to the subtraction of large numbers of nearly equal size. These inaccuracies occured mostly in the calculation of forces and moments near discontinuities. In order to minimize these errors without having to resort to a computer program written entirely in double precision, the present formulation reduces the field equations to eight first-order equations in terms of the eight variables, u, v, w, ω_{θ}, $\overline{N}_{\phi\theta}$, N_{ϕ}, $\overline{Q}_{\phi}$ and M_{ϕ}. In this formulation, boundary conditions and discontinuity equations do not involve any derivatives. Experience with using the eight first-order equations indicates that the inaccuracies obtained with the four second-order equations were eliminated, and comparisons of results from the two formulations has shown that the eight first-order equations yield more accurate results for the same number of pivotal points.

The eight first-order equations have previously been used for solving linear shell problems, (References 4 and 5). These authors used a numerical integration technique to solve these equations. It was pointed out by Kalnins, (Reference 4), that the numerical integration technique does have one serious liability; a loss of accuracy can result when the length of the shell increases. This inaccuracy results from the subtraction of almost equal numbers in the process of determining the boundary conditions. Kalnins showed that this inaccuracy could be minimized by segmenting the shell, and thereby, integrate only over short intervals. His method of solution consists of finding the influence coefficients for short intervals by numerical integration. After determining these quantities, continuity conditions on all variables at the ends of contiguous intervals are specified and constitute a set of simultaneous equations which are then solved. The finite difference method does not have this type of inaccuracy problem, and for this reason was used in the present investigation.

Following the method presented by Kalnins, (Reference 4), the governing eight first-order equations will now be derived. First it is necessary to express N_θ, M_θ and $M_{\phi\theta}$ in terms of the eight fundamental variables, u, v, w, ω_θ, $\overline{N}_{\phi\theta}$, N_ϕ, $\overline{Q}_\phi$ and M_ϕ. From equations (3), (4) and (5) one may obtain

$$N_\theta = \mu N_\phi + D(1 - \mu^2)\left[\frac{1}{r}(v \cos\phi + u' + w \sin\phi) + \frac{1}{2}(\omega_\phi^2 + \omega^2)\right] \tag{6}$$

$$M_\theta = \mu M_\phi + \frac{K(1 - \mu^2)}{r}\left[-\frac{w''}{r} + u'\frac{\sin\phi}{r} + \omega_\theta \cos\phi\right] \tag{7}$$

$$M_{\phi\theta} = \frac{K(1 - \mu)}{2}\left[\frac{2\omega_\theta'}{r} + \frac{2w' \cos\phi}{r^2} - \frac{3}{2} u \frac{\sin\phi \cos\phi}{r^2} - \frac{1}{2} v' \frac{\sin\phi}{r^2} + \frac{3}{2} u^{\cdot} \frac{\sin\phi}{r}\right] \tag{8}$$

To eliminate the term involving $u^{\cdot}$ in equation (8), we use equations (2b), (3c) and (4c), i.e.,

$$u^{\cdot} = \frac{2N_{\phi\theta}}{D(1 - \mu)} - \frac{v'}{r} + \frac{u \cos\phi}{r} - \omega_\phi \omega_\theta$$

or in terms of $\overline{N}_{\phi\theta}$

$$u^{\cdot} = \frac{2}{D(1-\mu)}\left[\overline{N}_{\phi\theta} - \frac{3}{2} M_{\phi\theta} \frac{\sin\phi}{r} - \frac{1}{2}(N_\phi + N_\theta)\omega\right] - \frac{v'}{r} + u\frac{\cos\phi}{r} - \omega_\phi\omega_\theta \tag{9}$$

Substituting (9) into (8) yields

$$M_{\phi\theta} = \frac{K(1-\mu)}{2L}\left\{\frac{2\omega'_\theta}{r} + \frac{2w'\cos\phi}{r^2} - \frac{2v'\sin\phi}{r^2} - \frac{3}{2}\omega_\phi\omega_\theta\frac{\sin\phi}{r} + \frac{3\sin\phi}{D(1-\mu)r}\left[\overline{N}_{\phi\theta} - \frac{1}{2}(N_\phi + N_\theta)\omega\right]\right\} \tag{10}$$

where

$$L = 1 + \frac{9}{4}\frac{K}{D}\frac{\sin^2\phi}{r^2} \tag{11}$$

The derivation of the basic eight first-order equations in the independent variable, S, can now be obtained. From equations (2) we have

$$N_{\phi\theta} = \overline{N}_{\phi\theta} - \frac{3}{2} M_{\phi\theta}\frac{\sin\phi}{r} - \frac{1}{2}(N_\phi + N_\phi)\omega \tag{12}$$

$$Q_\phi = \overline{Q}_\phi - \frac{M'_{\phi\theta}}{r} + (N_\phi\omega_\theta + N_{\phi\theta}\omega_\phi) \tag{13}$$

Substituting equations (12) and (13) into equations (1a - 1d) yields

$$\overline{N}^{\cdot}_{\phi\theta} + 2\overline{N}_{\phi\theta}\frac{\cos\phi}{r} + \frac{N'_\theta}{r} + M'_\theta\frac{\sin\phi}{r^2} - \frac{\sin\phi}{r}(N_{\phi\theta}\omega_\theta + N_\theta\omega_\phi) - \left[(N_\phi + N_\theta)\omega\right]\frac{\cos\phi}{r} + \overline{Z}\omega_\phi + \overline{X} = 0 \tag{14a}$$

$$N_\phi^\bullet + (N_\phi - N_\theta)\frac{\cos\phi}{r} + \frac{\overline{N}'_{\phi\theta}}{r} - 2M'_{\phi\theta}\frac{\sin\phi}{r^2} + \frac{1}{r}\left[(N_\phi + N_\theta)\omega\right]' + \overline{Z}\omega_\theta + \overline{Y} = 0 \tag{14b}$$

$$\overline{Q}_\phi^\bullet + \overline{Q}_\phi\frac{\cos\phi}{r} - N_\theta\frac{\sin\phi}{r} + 2M'_{\phi\theta}\frac{\cos\phi}{r^2} + \frac{M''_\theta}{r^2} - (N_{\phi\theta}\omega_\theta + N_\theta\omega_\phi)' + \overline{Z}(1 + \overline{\varepsilon}_\phi + \overline{\varepsilon}_\theta) = 0 \tag{14c}$$

$$M_\phi^\bullet + (M_\phi - M_\theta)\frac{\cos\phi}{r} + \frac{2M'_{\phi\theta}}{r} - \overline{Q}_\phi - (N_\phi\omega_\theta + N_{\phi\theta}\omega_\phi) = 0 \tag{14d}$$

The other four equations are obtained from equations (3), (4), (5) and (9).

$$u^\bullet + \frac{v'}{r} - \frac{u\cos\phi}{r} - \frac{2}{D(1-\mu)}\left[\overline{N}_{\phi\theta} - \frac{3}{2}M_{\phi\theta}\frac{\sin\phi}{r}\right] + \omega_\phi\omega_\theta + \frac{1}{D(1-\mu)}\left[(N_\phi + N_\theta)\omega\right] = 0 \tag{14e}$$

$$v^\bullet - \frac{1}{D(1-\mu^2)}(N_\phi - \mu N_\theta) + \frac{1}{2}(\omega_\theta^2 + \omega^2) = 0 \tag{14f}$$

$$W^\bullet + \omega_\theta = 0 \tag{14g}$$

$$\omega_\theta^\bullet - \frac{1}{K(1-\mu^2)}(M_\phi - \mu M_\theta) = 0 \tag{14h}$$

Thus, equations (14) together with (6), (7) and (10) are the governing differential equations.

1.2.5 Fourier Series Expansion

The derivatives of the variables with respect to the circumferential coordinate are eliminated by expanding the variables into Fourier series in

the circumferential direction. In the present formulation, only symmetric loading about a meridional plane will be considered. For this case the variables have expansions of the form

$$\{\overline{X},\ N_{\phi\theta},\ \overline{N}_{\phi\theta},\ Q_\theta,\ M_{\phi\theta},\ u,\ \omega,\ \omega_\phi\} = \sum_{M=1}^{\infty} \left\{ \overline{X}_M,\ N_{\phi\theta_M},\ \overline{N}_{\phi\theta_M},\ Q_{\theta_M},\ u_M,\ \omega_M,\ \omega_{\phi_M} \right\} \left\{ \sin M\theta \right\} \tag{15}$$

$$\{\overline{Y},\ \overline{Z},\ N_\phi,\ N_\theta,\ Q_\phi,\ \overline{Q}_\phi,\ M_\phi,\ M_\theta,\ v,\ w,\ \omega_\theta\} =$$

$$\sum_{M=0}^{\infty} \left\{ \overline{Y}_M,\ \overline{Z}_M,\ N_{\phi_M},\ N_{\theta_M},\ Q_{\phi_M},\ \overline{Q}_{\phi_M},\ M_{\phi_M},\ M_{\theta_M},\ v_M,\ w_M,\ \omega_{\theta_M} \right\} \left\{ \cos M\theta \right\}$$

If we substitute equations (6), (7), (10) and (15) into equations (14), and collect terms of like trigonometric arguments, the governing eight first-order differential equations for any harmonic, M, are obtained

$$\begin{Bmatrix} \overline{N}^{\cdot}_{\phi\theta} \\ N^{\cdot}_{\phi} \\ \overline{Q}^{\cdot}_{\phi} \\ M^{\cdot}_{\phi} \\ u^{\cdot} \\ v^{\cdot} \\ w^{\cdot} \\ \omega^{\cdot}_{\theta} \end{Bmatrix}_M + \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{18} \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ A_{81} & A_{82} & \cdots & A_{88} \end{bmatrix} \begin{Bmatrix} u \\ v \\ w \\ \omega_\theta \\ \overline{N}_{\phi\theta} \\ N_\phi \\ \overline{Q}_\phi \\ M_\phi \end{Bmatrix}_M = \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \\ P_6 \\ P_7 \\ P_8 \end{Bmatrix}_M \tag{16}$$

where A_{11}, A_{12} etc. are given in Appendix A. The terms in right-hand vector are given by

$$P_{1_M} = -\overline{X}_M + \frac{\sin\phi}{r}\lambda_M^{(1)} + \frac{\cos\phi}{r}\lambda_M^{(2)} + \frac{D(1-\mu^2)}{2r} M\,\lambda_M^{(3)} - \lambda_M^{(8)} \tag{17a}$$

$$P_{2_M} = -\bar{Y}_M + \frac{M}{r}\left(1 - \frac{3K\sin^2\phi}{2DLr^2}\right)\lambda_M^{(2)} + D(1-\mu^2)\frac{\cos\phi}{2r}\lambda_M^{(3)} \tag{17b}$$

$$- \frac{3}{2}\frac{MK(1-\mu)}{Lr^3}(\sin^2\phi)\lambda_M^{(4)} - \lambda_M^{(7)}$$

$$P_{3_M} = -\bar{Z}_M + \frac{M}{r}\lambda_M^{(1)} + \left(\frac{3MK}{2DLr^3}\sin\phi\cos\phi\right)\lambda_M^{(2)} \tag{17c}$$

$$+ D(1-\mu^2)\frac{\sin\phi}{2r}\lambda_M^{(3)} + \frac{3MK(1-\mu)}{2Lr^3}(\sin\phi\cos\phi)\lambda_M^{(4)} - \lambda_M^{(9)}$$

$$P_{4_M} = \frac{3MK}{2DLr^2}\lambda_M^{(2)} + \frac{3MK(1-\mu)}{2Lr^2}(\sin\phi)\lambda_M^{(4)} + \lambda_M^{(5)} \tag{17d}$$

$$P_{5_M} = -\frac{1}{LD(1-\mu)}\lambda_M^{(2)} - \frac{\lambda_M^{(4)}}{L} \tag{17e}$$

$$P_{6_M} = -\frac{1}{2}\left(\lambda_M^{(6)} + \mu\lambda_M^{(3)}\right) \tag{17f}$$

$$P_{7_M} = P_{8_M} = 0 \tag{17g}$$

where the λ's are given in Appendix B

1.2.6 Force, Moment and Rotation Equations

The forces, moments, and rotations which are not included in the fundamental variables are obtained, for any harmonic, from equations (2), (5), (6), (7), (10) and (15). They are

$$N_{\theta_M} = \mu N_{\phi_M} + D(1-\mu^2)\left[\frac{1}{r}(v_M\cos\phi + Mu_M + w_M\sin\phi) + \frac{1}{2}\lambda_M^{(3)}\right] \tag{18a}$$

$$N_{\phi\theta_M} = \frac{\bar{N}_{\phi\theta_M}}{L} + \frac{3K(1-\mu)}{2Lr^2}\sin\phi\left(Mw_M\frac{\cos\phi}{r} + M\omega_{\theta_M} - Mv_M\frac{\sin\phi}{r}\right. \tag{18b}$$

$$\left. + \frac{3}{4}\lambda_M^{(4)}\sin\phi\right) - \frac{\lambda_M^{(2)}}{2L}$$

$$M_{\theta_M} = \mu M_{\phi_M} + \frac{K(1 - \mu^2)}{r} \quad M^2\left[\frac{w_M}{r} + Mu_M \frac{\sin \phi}{r} + \omega_{\theta_M} \cos \phi\right] \tag{18c}$$

$$M_{\phi\theta_M} = \frac{K(1 - \mu)}{2Lr} - 2M\omega_{\theta_M} - 2Mw_M \frac{\cos \phi}{r} + 2Mv_M \frac{\cos \phi}{r} \tag{18d}$$

$$+ \frac{3 \sin \phi}{D(1 - \mu)} \overline{N}_{\phi\theta_M} - \frac{3}{2} \sin \phi \left[\frac{\lambda_M^{(2)}}{D(1 - \mu)} + \lambda_M^{(4)}\right]$$

$$\omega_{\phi_M} = \frac{1}{r} (Mw_M + u_M \sin \phi) \tag{18e}$$

$$\omega_M = \frac{1}{2}\left(u_M^{\cdot} + u_M \frac{\cos}{r} + \frac{Mv_M}{r}\right) \tag{18f}$$

In equation (18f) the term $u_M^{\cdot}$ may be eliminated by the use of equation (14e); however, it is easier to evaluate $u_M^{\cdot}$ by the finite difference method.

1.3 Solution Technique

1.3.1 Iterative Method

Equations (16) are a nonlinear set of first-order differential equations. Moreover, because of the nonlinear terms (i.e., λ's), the equations for each Fourier index, M, are not uncoupled as is the case for the linear analyses. A number of iterative methods were investigated for solving these nonlinear equations. The simplest method, which was used by Ball, (Reference 11), considers the nonlinear terms as pseudo loading terms. The solution for the nth + 1 iteration of the nonlinear equations is obtained by using the solution for the nth iteration to calculate the pseudo load terms (i.e, $P_{\ell m}$ thru P_{8m}). In this technique the equations for each Fourier index are uncoupled since the non-linear terms are placed in the right-hand vector. Furthermore, this technique involves changing only the right-hand vector for each iteration and is therefore quite fast. The major disadvantage of this method is that it has extremely poor convergence properties and sometimes it will not converge at all. In fact, when this method was tried in the present investigation, it was found that the solution diverged.

Another iteration method for solving nonlinear equations is Newton's method, (Reference 14). In Newton's method, the solution of the equations is expressed as the sum of two parts. The first part is an assumed solution and the second part is a correction to the assumed solution, i.e.,

$$\{Y\}_{n+1} = \{Y_n\} + \{\Delta Y\} \tag{19}$$

Substitution of equation (19) into the governing equations (16), and neglecting terms which are nonlinear in ΔY , yields a system of linear equations from which the corrections, ΔY, may be determined. This method usually has good convergence properties but is quite time consuming as each iteration involves changing both the left and right side of the governing equations. Furthermore, when this method is carried out, the left side of the equations involve coupled harmonic equations and therefore the complete set of equations must be solved simultaneously. The task of repeatedly solving these equations until the solution converges requires excessive computation time.

The method which was used in the present investigation is essentially a compromise between the two methods given above. In this method equation (19) is substituted into the governing equations (16); however, all terms which couple harmonics on the left side of the equations are omitted so that the equations remain uncoupled. Also, in the present method, although the right side of the equations are recalculated after each iteration, the left side of the equations are only changed after a specified number of iterations, i.e., when convergence of the solution becomes poor. This technique has been found to work quite well and exhibits good convergence properties.

The fundamental variables are expressed as

$$\begin{Bmatrix} u \\ v \\ w \\ \omega_\theta \\ \overline{N}_{\phi\theta} \\ N_\phi \\ \overline{Q}_\phi \\ M_\phi \end{Bmatrix}_M = \begin{Bmatrix} u \\ v \\ w \\ \omega_\theta \\ \overline{N}_{\phi\theta} \\ N_\phi \\ \overline{Q}_\phi \\ M_\phi \end{Bmatrix}_M + \begin{Bmatrix} \Delta u \\ \Delta v \\ \Delta w \\ \Delta\omega_\theta \\ \Delta\overline{N}_{\phi\theta} \\ \Delta N_\phi \\ \Delta\overline{Q}_\phi \\ \Delta M_\phi \end{Bmatrix}_M \tag{20}$$

Substituting equations (20) into equations (16), neglecting nonlinear terms in $\Delta u, \Delta v$, etc., and all terms on the left side of the equations which couple Fourier harmonics, yield the following set of equations for any harmonic M,

$$\begin{Bmatrix} \Delta\dot{N}_{\phi\theta} \\ \Delta\dot{N}_\phi \\ \Delta\dot{\overline{Q}}_\phi \\ \Delta\dot{M}_\phi \\ \Delta\dot{u} \\ \Delta\dot{v} \\ \Delta\dot{w} \\ \Delta\dot{\omega}_\theta \end{Bmatrix}_M + \begin{bmatrix} A^*_{11} & A^*_{12} & \cdots & A^*_{18} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ A^*_{81} & A^*_{82} & \cdots & A^*_{88} \end{bmatrix} \begin{Bmatrix} \Delta u \\ \Delta v \\ \Delta w_\theta \\ \Delta\omega_\theta \\ \Delta\overline{N}_{\phi\theta} \\ \Delta N_\phi \\ \Delta Q_\phi \\ \Delta M_\phi \end{Bmatrix}_M = \begin{Bmatrix} P^*_1 \\ P^*_2 \\ P^*_3 \\ P^*_4 \\ P^*_5 \\ P^*_6 \\ P^*_7 \\ P^*_8 \end{Bmatrix}_M$$

or in concise matrix form

$$\{\Delta Y^{\cdot}\}_M + [A^*]\ \{\Delta Y\}_M = \{P^*\}_M \tag{21}$$

where $\{\Delta Y\}_M$ is the vector of the fundamental variables and $[A^*]$ is the matrix of coefficients whose terms are given in Appendix C. The terms of the right hand vector $\{P^*\}_M$ are the governing differential equations and are given by

$$\begin{aligned}
P^*_{1_M} &= R_{1_M} + \frac{\sin\phi}{r}\ \lambda_M^{(1)} + \frac{\cos\phi}{r}\ \lambda_M^{(2)} - \lambda_M^{(8)} \\
P^*_{2_M} &= R_{2_M} + \frac{M}{r}\ \lambda_M^{(2)} - \lambda_M^{(7)} \\
P^*_{3_M} &= R_{3_M} + \frac{M}{r}\ \lambda_M^{(1)} - \lambda_M^{(9)} \\
P^*_{4_M} &= R_{4_M} + \lambda_M^{(5)} \\
P^*_{5_M} &= R_{5_M} - \frac{\lambda_M^{(2)}}{D(1-\mu)} - \lambda_M^{(4)} \\
P^*_{6_M} &= R_{6_M} - \frac{1}{2}\ \lambda_M^{(6)} \\
P^*_{7_M} &= R_{7_M} \\
P^*_{8_M} &= R_{8_M}
\end{aligned} \tag{22}$$

where

$$R_{1_M} = -\left[\overline{N}^{\cdot}_{\phi\theta_M} + 2N_{\phi\theta_M}\ \frac{\cos\phi}{r} - \frac{M}{r}\ N_{\theta_M} - M\ M_\theta\ \frac{\sin\phi}{r} + \overline{X}\right]$$

$$R_{2_M} = -\left[N^{\cdot}_{\phi_M} + (N_{\phi_M} - N_{\theta_M})\ \frac{\cos\phi}{r} + \frac{M}{r}\ \overline{N}_{\phi\theta_M} - \frac{2M\sin\phi}{r^2}\ M_{\phi\theta_M} + \overline{Y}\right]$$

$$R_{3_M} = -\left[\dot{\overline{Q}}_{\phi_M} + \overline{Q}_{\phi_M}\frac{\cos\phi}{r} - N_{\theta_M}\frac{\sin\phi}{r} + 2M\,M_{\phi\theta}\frac{\cos\phi}{r^2} - \frac{M^2}{r^2}M_{\theta_M} + \overline{Z}\right]$$

$$R_{4_M} = -\left[\dot{M}_{\phi_M} + (M_{\phi_M} - M_{\theta_M})\frac{\cos\phi}{r} + \frac{2M}{r}M_{\phi\theta_M} - \overline{Q}_{\phi_M}\right]$$

$$R_{5_M} = -\left[\dot{u}_M - \frac{M}{r}v_M - u_M\frac{\cos\phi}{r} - \frac{2}{D(1-\mu)}\left(\overline{N}_{\phi\theta_M} - \frac{3}{2}M_{\phi\theta}\frac{\sin\phi}{r}\right)\right]$$

$$R_{6_M} = -\left[\dot{v}_M - \frac{1}{D(1-\mu^2)}(N_{\phi_M} - \mu N_{\theta_M})\right]$$

$$R_{7_M} = -\left[\dot{w}_M + \omega_{\theta_M}\right]$$

$$R_{8_M} = -\left[\dot{\omega}_{\theta_M} - \frac{1}{K(1-\mu^2)}(M_{\phi_M} - \mu M_{\theta_M})\right] \tag{23}$$

1.3.2 Finite Difference Representation

The governing first-order differential equations are now reduced to a system of algebraic equations by use of the finite difference method. One method of solving simultaneous first-order differential equations is given by Fox (Reference 15). The first derivative of a variable at pivotal points, n and n+1, may be expressed in terms of the variables at these points, i.e.,

$$\frac{1}{2}(\dot{Y}_{n+1} + \dot{Y}_n) = \frac{1}{d}(Y_{n+1} - Y_n) + \varepsilon\, Y_{n+1/2} \tag{24}$$

where

$$\varepsilon = O(d^2)$$

$$d = S_{n+1} - S_n$$

ε, the error term in equation (24) is of the order of magnitude of the spacing squared. By using equation (24) and neglecting ε, equations (21) may be replaced by the algebraic equations

$$\left[\frac{1}{2}\,[A^*]_{n+1} + \frac{1}{d}\,[I]\right]\{\Delta Y\}_{n+1} + \left[\frac{1}{2}\,[A^*]_n - \frac{1}{d}\,[I]\right]\{\Delta Y\}_n$$

$$= \frac{1}{2}\,\{P^*\}_n + \frac{1}{2}\,\{P\}_{n+1} = \{F\} \tag{25}$$

where, for conciseness, matrix notation has been used, and for convenience the subscript M, referring to the Fourier index, has been omitted. The subscripts n and n+1 refer to the pivotal points, and specify the points at which [A*], {ΔY} and {P*} are evaluated. The terms in the vector {F} are given by

$$F_1 = -\sum_{\ell=n}^{n+1} \frac{1}{2}\left[\left(\frac{2\cos\phi}{r_\ell} + \frac{2}{d_\ell}\right)\overline{N}_{\phi\theta_\ell} - MN_{\theta_\ell} - MM_{\theta_\ell}\frac{\sin\phi}{r_\ell^2} + \overline{X}_\ell - \lambda_\ell^{(1)}\frac{\sin\phi}{r_\ell} - \lambda_\ell^{(2)}\frac{\cos\phi}{r_\ell} + \lambda_\ell^{(8)}\right]$$

$$F_2 = -\sum_{\ell=n}^{n+1} \frac{1}{2}\left[\left(\frac{\cos\phi}{r_\ell} + \frac{2}{d_\ell}\right)N_{\phi_\ell} - N_{\theta_\ell}\frac{\cos\phi}{r_\ell} + M\frac{\overline{N}_{\phi\theta_\ell}}{r_\ell} - 2M\frac{M_{\phi\theta_\ell}}{r_\ell^2} + \overline{Y}_\ell - \frac{M}{r_\ell}\lambda_\ell^{(2)} + \lambda_\ell^{(7)}\right]$$

$$F_3 = -\sum_{\ell=n}^{n+1} \frac{1}{2}\left[\left(\frac{\cos\phi}{r_\ell} + \frac{2}{d_\ell}\right)\overline{Q}_{\phi_\ell} - N_{\theta_\ell}\frac{\sin\phi}{r_\ell} + 2MM_{\phi\theta_\ell}\frac{\cos\phi}{r_\ell^2} - \frac{M^2}{r_\ell^2}M_{\theta_\ell} + \overline{Z}_\ell - \frac{M}{r_\ell}\lambda_\ell^{(1)} + \lambda_\ell^{(9)}\right] \tag{26}$$

$$F_4 = -\sum_{\ell=n}^{n+1} \frac{1}{2}\left[\left(\frac{\cos\phi}{r_\ell} + \frac{2}{d_\ell}\right)M_{\phi_\ell} - M_{\Theta_\ell}\frac{\cos\phi}{r_\ell} + \frac{2M}{r_\ell}M_{\phi\theta_\ell} - \overline{Q}_{\phi_\ell} - \lambda_\ell^{(5)}\right]$$

$$F_5 = -\sum_{\ell=n}^{n+1} \frac{1}{2}\left[-\left(\frac{\cos\phi}{r_\ell} + \frac{2}{d_\ell}\right)u_\ell - \frac{M}{r_\ell}v_\ell - \frac{2}{D_\ell(1-\mu_\ell)}\left(N_{\phi\theta_\ell} - \frac{3}{2}M_{\phi\theta_\ell}\frac{\sin\phi}{r_\ell}\right) + \frac{1}{D_\ell(1-\mu_\ell)}\lambda_\ell^{(2)} + \lambda_\ell^{(4)}\right]$$

$$F_6 = - \sum_{\ell=n}^{n+1} \frac{1}{2} \left[\frac{2}{d_\ell} v_\ell - \frac{1}{D_\ell(1 - \mu_\ell^2)} \left(N_{\phi_\ell} - \mu N_{\theta_\ell} \right) + \frac{1}{2} \lambda_\ell^{(6)} \right]$$

$$F_7 = - \sum_{\ell=n}^{n+1} \frac{1}{2} \left[\frac{2}{d_\ell} w_\ell + \omega_{\theta_\ell} \right]$$

$$F_8 = - \sum_{\ell=n}^{n+1} \frac{1}{2} \left[\frac{2}{d_\ell} \omega_{\theta_\ell} - \frac{1}{K_\ell(1 - \mu_\ell^2)} \left(M_{\phi_\ell} - \mu M_{\theta_\ell} \right) \right]$$

where $d_\ell = - (S_{n+1} - S_n)$ for $\ell = n$

$d_\ell = (S_{n+1} - S_n)$ for $\ell = n+1$

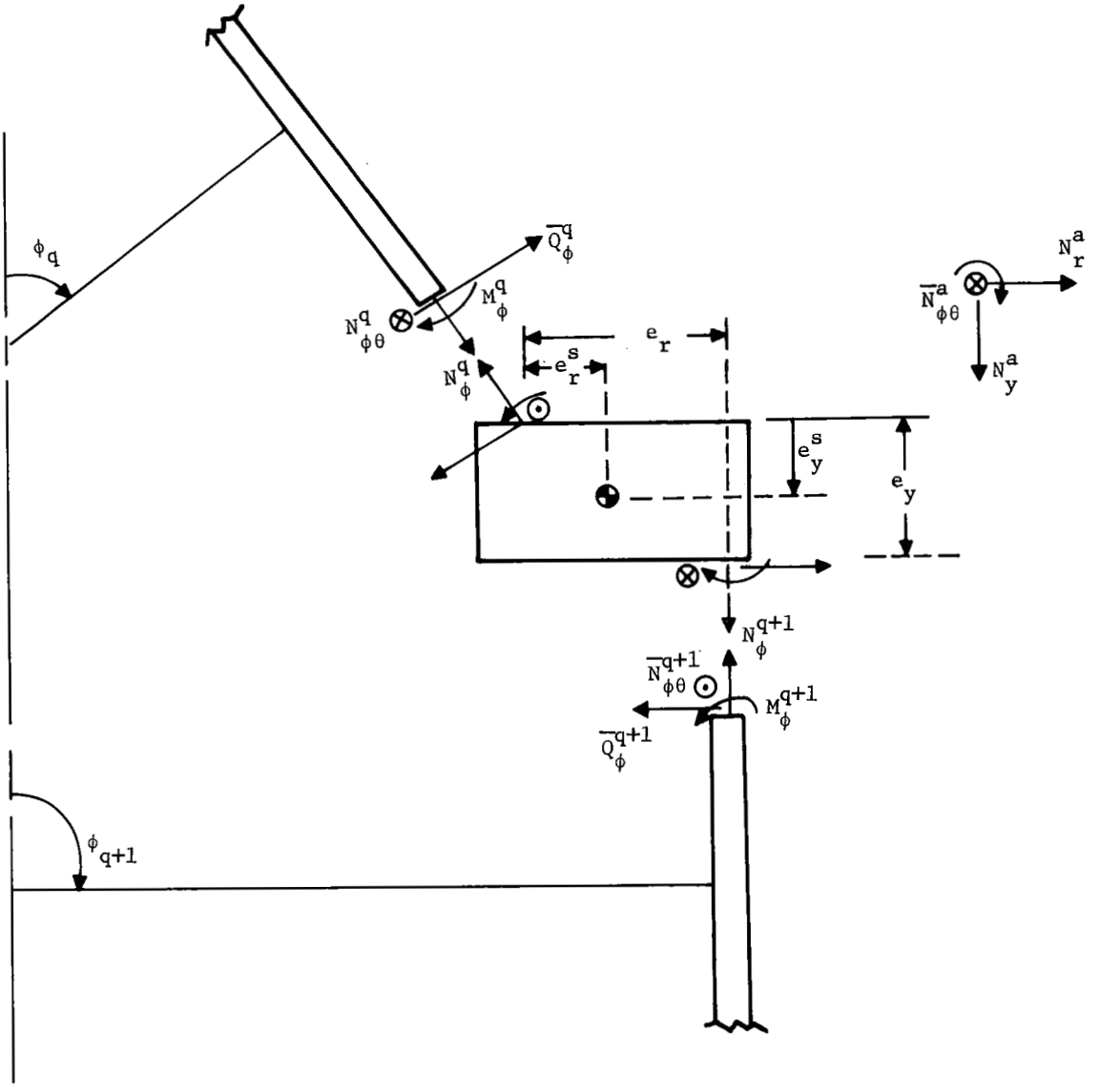
and the subscript M, referring to the Fourier index, has been omitted for convenience.

Equations (25) may be considered as the result of applying the differential equations at a point half-way between the pivoted points n and n+1. If there are n pivotal points, there are 8n unknowns. The use of equation (25) at every internal half-way point gives 8(n-1) equations, and the remaining eight equations are obtained from the boundary conditions.

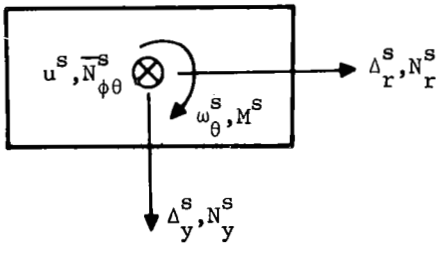
1.3.3 Discontinuity Equations

In most practical shell problems, discontinuities in geometry occur. The differential equations (25) are not valid at discontinuities because at these points the variables may be discontinuous. Accordingly, special transition equations must be derived which maintain continuity of forces, moments, and displacements across the discontinuity. Discrete rings and line loads are also included in the derivation of the discontinuity equations.

A typical discontinuity is illustrated in Figure 1.2. In this model two unequal angle cones are connected together by an elastic support. A total of eight equations are needed to specify continuity of displacements and rotations and equilibrium of forces and moments at the discontinuity. For what follows, the superscripts, q and q+1, refer to the conical shell segment forces and displacements on either side of the discontinuity. The



1.2(a) Positive Direction of the Forces Acting at the Discontinuity Point



1.2(b) Positive Direction of the Forces Acting on the Elastic Support

Figure 1.2 Typical Discontinuity Point

applied line loads will be denoted by the superscript,"a", and the forces and moments acting on the shell due to elastic support are denoted by the superscript, "s". Equilibrium of forces and moments at the discontinuity requires that

$$r^q \overline{N}_{\phi\theta}^q - r^{q+1} \overline{N}_{\phi\theta}^{q+1} + r^s \overline{N}_{\phi\theta}^s = r^a \overline{N}_{\phi\theta}^a \tag{27a}$$

$$r^q N_\phi^q - r^{q+1} (N_\phi^{q+1} \cos \psi + \overline{Q}_\phi^{q+1} \sin \psi) + r^s N_\phi^s \tag{27b}$$

$$= r^a (N_r^a \cos \phi_q + N_y^a \sin \phi_q)$$

$$r^q \overline{Q}_\phi^q - r^{q+1} (-N_\phi^{q+1} \sin \psi + \overline{Q}_\phi^{q+1} \cos \psi) + r^s Q_\phi^s \tag{27c}$$

$$= r^a (N_r^a \sin \phi_q - N_y^a \cos \phi_q)$$

$$r^q M_\phi^q - r^{q+1} M_\phi^{q+1} - r^{q+1} N_\phi^{q+1} (e_r \sin \phi_{q+1} - e_y \cos \phi_{q+1}) \tag{27d}$$

$$+ r^{q+1} \overline{Q}_\phi^{q+1} (e_r \cos \phi_{q+1} + e_y \sin \phi_{q+1}) + r^s M_\phi^s$$

$$= r^a M_\phi - r^{q+1} N_\phi^{q+1} \omega_\theta^{q+1} (e_r \cos \phi_{q+1} + e_y \sin \phi_{q+1})$$

where $\psi = \phi_{q+1} - \phi_q$

In equations (27) the applied line loads are assumed to be applied at the end of segment q (i.e., $r^a = r^q$). The nonlinear term in equations (27d) is in keeping with the assumption of moderately small rotations. The support forces will now be expressed in terms of the displacement of the last point in segment q. The stiffness matrix for the elastic support is (see Figure 1.2 for the positive sign conventions)

$$\begin{Bmatrix} \overline{N}^s_{\phi\theta} \\ N^s_y \\ N^s_r \\ M^s \end{Bmatrix} = \begin{bmatrix} C_1 & C_2 & C_3 & C_4 \\ C_5 & C_6 & C_7 & C_8 \\ C_9 & C_{10} & C_{11} & C_{12} \\ C_{13} & C_{14} & C_{15} & C_{16} \end{bmatrix} \begin{Bmatrix} u^s \\ \Delta^s_y \\ \Delta^s_r \\ \omega^s_\theta \end{Bmatrix} \tag{28}$$

or in matrix form

$$\{P^s\} = [C]\ \{\Delta\} \tag{29}$$

The displacements of the c.g. of the support are related to the displacements of the last point of segment q by the equations.

$$\begin{Bmatrix} u^s \\ \Delta^s_y \\ \Delta^s_r \\ \omega^s_\theta \end{Bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{Bmatrix} u^q \\ v^q \\ w^q \\ \omega^q_\theta \end{Bmatrix} \tag{30}$$

where

$$a_{11} = 1 + \frac{e^s_r}{r^q} \tag{31}$$

$$a_{12} = \frac{M}{r^q}\left(e^s_r \cos\phi_q + e^s_y \sin\phi_q\right)$$

$$a_{13} = \frac{M}{r^q}\left(e^s_r \sin\phi_q - e^s_y \cos\phi_q\right)$$

$$a_{22} = \sin\phi_q$$

$$a_{23} = -\cos\phi_q$$

$$a_{24} = e^s_r$$

$$a_{32} = \cos\phi_q$$

$$a_{33} = \sin \phi_q \qquad (31) \text{ (cont.)}$$

$$a_{34} = -e_y^s$$

$$a_{44} = 1.0$$

All other "a" coefficients are zero. Substituting equation (30) into (29) and multiplying the resultant equation by $[a]^T$ yields the relations between the support forces and the displacements of segment q.

$$\begin{Bmatrix} N_{\phi\theta}^s \\ N_\phi^s \\ \overline{Q}_\phi^s \\ M_\phi^s \end{Bmatrix} = \begin{bmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ k_{41} & k_{42} & k_{43} & k_{44} \end{bmatrix} \begin{Bmatrix} u^q \\ v^q \\ w^q \\ \omega_\theta^q \end{Bmatrix} \qquad (32)$$

where

$$[k] = [a]^T [C][a] \qquad (33)$$

Substituting equation (32) into equation (27) gives the governing equilibrium equations at the discontinuity

$$\frac{r^s}{r^q} (k_{11}u^q + k_{12}v^q + k_{13}w^q + k_{14}\omega_\theta^q) + \overline{N}_{\phi\theta}^q - \frac{r^{q+1}}{r^q} \overline{N}_{\phi\theta}^{q+1} = \overline{N}_{\phi\theta}^a \qquad (34)$$

$$\frac{r^s}{r^q} (k_{21}u^q + k_{22}v^q + k_{23}w^q + k_{24}\omega_\theta^q) + N_\phi^q$$

$$- \frac{r^{q+1}}{r^q} (N_\phi^{q+1} \cos \psi + \overline{Q}_\phi^{q+1} \sin \psi) = N_r^a \cos \phi_q + N_y^a \sin \phi_q$$

$$\frac{r^s}{r^q} (k_{31}u^q + k_{32}v^q + k_{33}w^q + k_{34}\omega_\theta^q) + \overline{Q}_\phi^q$$

$$- \frac{r^{q+1}}{r^q} (-N_\phi^{q+1} \sin \psi + \overline{Q}_\phi^{q+1} \cos \psi) = N_r^a \sin \phi_q - N_y^a \cos \phi_q$$

$$\frac{r^s}{r^q}\left(k_{41}u^q + k_{42}v^q + k_{43}w^q + k_{44}\omega_\theta^q\right) + M_\phi^q - \frac{r^{q+1}}{r^q} M_\phi^{q+1} \tag{34 (cont.)}$$

$$- \frac{r^{q+1}}{r^q} N_\phi^{q+1} \left(e_r \sin \phi_{q+1} - e_y \cos \phi_{q+1}\right)$$

$$+ \overline{Q}^{q+1} \left(e_r \cos \phi_{q+1} + e_y \sin \phi_{q+1}\right)$$

$$= M_\phi^a - \frac{r^{q+1}}{r^q} N_\phi^{q+1} \omega_\theta^{q+1} \left(e_r \cos \phi_{q+1} + e_y \sin \phi_{q+1}\right)$$

The continuity equations for displacements and rotations are given by

$$\left(1 + \frac{e_r}{r^q}\right) u^q + \frac{M}{r^q}\left(e_r \cos \phi_q + e_y \sin \phi_q\right) v^q \tag{35}$$

$$+ \frac{M}{r^q}\left(e_r \sin \phi_q - e_y \cos \phi_q\right) w^q - u^{q+1} = 0$$

$$v^q + \left(e_r \sin \phi_q - e_r \cos \phi_q\right) \omega_\theta^q - v^{q+1} \cos \psi - w^{q+1} \sin \psi = 0$$

$$w^q - \left(e_r \cos \phi_q + e_y \sin \phi_q\right) \omega_\theta^q + v^{q+1} \sin \psi - w^{q+1} \cos \psi = 0$$

$$\omega_\theta^q - \omega_\theta^{q+1} = 0$$

Finally, as in Section (3.1), substituting equations (20) into (34) and (35), neglecting nonlinear terms for the corrections ΔY, and all terms on the left side of the equations which couple Fourier harmonics, yields the discontinuity equations for the corrections to the fundamental variables. These equations will not be given since they are obtained in a straight forward manner.

1.3.4 Solution of the Algebraic Equations

The manner by which the boundary conditions, discontinuity equations, and the eight equations at each interior point are cast into a complete set, and the method of solving these equations will now be discussed. In general, complicated shell problems possess discontinuities and therefore must be segmented as shown in Figure 1.3a. The governing equations for each segment are obtained by subdividing the segment into small intervals as shown in Figure 1.3b. Normally, smaller intervals are needed where rapid variations of the solution occur. Thus, in the computer program developed for this analysis, smaller intervals may be specified near discontinuity and boundary points.

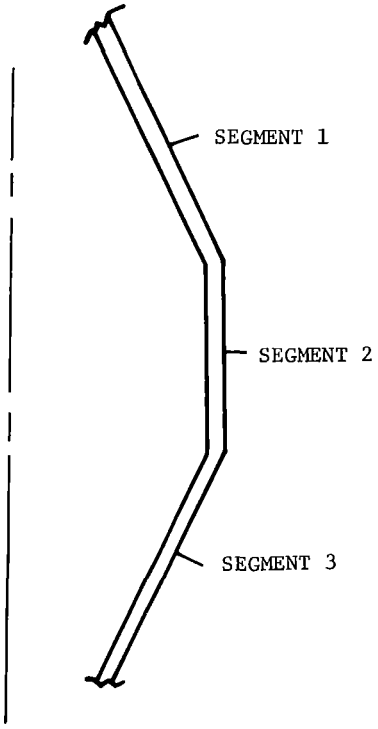
The algebraic equations for any harmonic are placed in the form shown in Figure 1.3c. The first four equations correspond to boundary conditions for the first point of segment 1. The next 8(n-1) equations, (n = number of points in segment 1), are the interior point equations (25). Eight discontinuity equations are then used to connect segments 1 and 2, etc.

When the complete set of equations is written in matrix notation. it can be seen that all non-zero terms of the matrix cluster about the main diagonal. This type of matrix is called a band matrix, and may be rapidly solved by a computer. For the present formulation, each row of the matrix contains only 16 terms. Furthermore, there are a maximum of 11 non-zero terms to the left or right of the main diagonal. Efficient computer storage may be obtained by storing the coefficients of this matrix in a rectangular array with the column of main diagonal terms placed in the middle of the array.

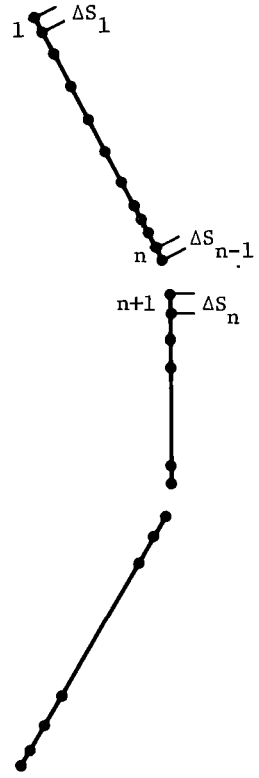
In the developed computer program, the Gaussian elimination method, (Reference 16), was used to solve the algebraic equations. This method will now be briefly described. Consider the system of simultaneous equations

$$[A]\ \{Y\} = \{P\} \tag{36}$$

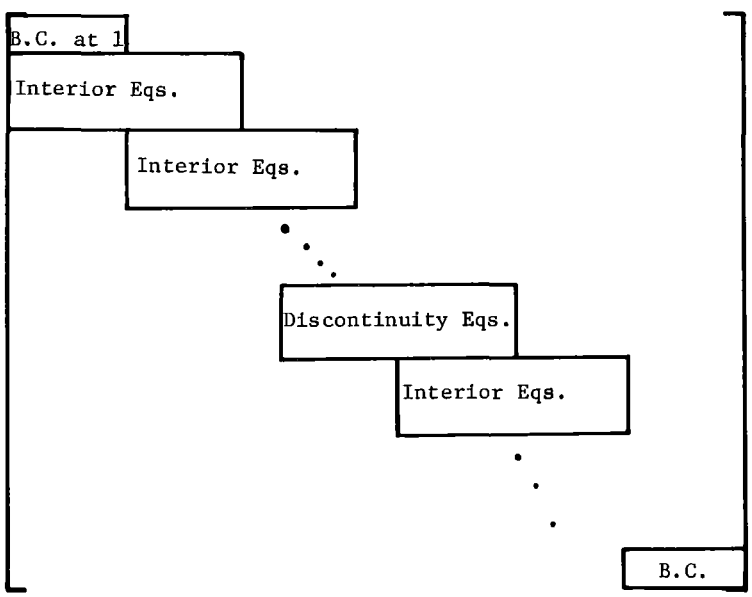
where [A] is a band matrix. The method of solving equations (36) for {Y} is basically that of triangularizing [A] by Gaussian elimination. This



1.3a Shell Segments



1.3b Finite Difference Intervals



1.3c Band Matrix of the Governing Equations

Figure 1.3 Mathematical Representation

is done by performing row operations on [A] and {P}. Mathematically, this can be expressed by the multiplication of both sides of equation (36) by a matrix [L] such that

$$[L][A] = [U] \tag{37}$$

where [U] is an upper triangular matrix. Thus one obtains

$$[L][A]\{Y\} = [L]\{P\} \tag{38}$$

or

$$[U]\{Y\} = \{C\} \tag{39}$$

where

$$\{C\} = [L]\{P\} \tag{40}$$

Since [U] is an upper triangular matrix, the solution of equations (39) is easily obtained by back substitution. By saving the upper triangular matrix [U] and the matrix [L], the solution for any new right-hand vector, {P}, may be easily determined.

In solving the nonlinear shell problem, the method described above is used to obtain the corrections to the solution vector for each harmonic M. After a new solution for any harmonic has been obtained, it is used in the calculation of the new right hand vectors for succeeding harmonics. This type of procedure is similar to a Gauss-Seidel iteration method and was found to work quite well. A complete description of the iteration method will now be given.

1.3.5 Iteration Procedure

The technique for determining the nonlinear solution can best be described in a step-by-step manner. This will be done by outlining the technique used in the computer program developed for this investigation.

1. The first step toward obtaining the complete solution is to find the nonlinear solution due only to axisymmetric loading. The iterative method used for this case is essentially the Newton

Method. A linear solution to equations (25) is first obtained, for harmonic M = 0, by setting the prior solution equal to zero. This solution is then used to calculate the new right-hand vector and to rebuild the "A*" coefficients (see Appendix C). The complete set of algebraic equations are then rebuilt and solved to obtain the corrections $\{\Delta Y\}$. This iterative technique (called a "special iteration") is repeated a specified number of times.

2. After the axisymmetric solution is obtained, it is used to calculate the "A*" coefficients for all harmonics under consideration.

3. The governing equations for all harmonics are obtained and solved to determine the matrices [U] and [L]. These matrices are retained so that the solution, due to any right-hand vector, may be obtained by the method described in Section 1.3.4.

4. The next iterative method (called an "ordinary iteration") consists of determining the solution for each harmonic, starting with M = 0, for the first prescribed nonsymmetric load level. As the new solution for each harmonic is obtained, it is used to calculate the new right-hand vector for succeeding harmonics. When all harmonics have been processed, the corrections to the solutions for all harmonics are compared with the sum of the solutions of all harmonics. If the ratio is larger than a specified number, step 4 is repeated until either the solution satisfies the convergence criteria or a specified maximum number of iterations have been exceeded.

5. If the solution has not converged at this time, the program will print the results so far obtained and stop. Two choices are then available to the user. He may either reduce the load level and the magnitude of the loading increments, and restart the program

at step 4, or he may ask that the solution obtained at this time be used to rebuild the governing equations. If the latter case is used, the program may be restarted at step 2 (called an "Update Option"). Normally, the latter case is needed when large nonlinear deformations have occurred.

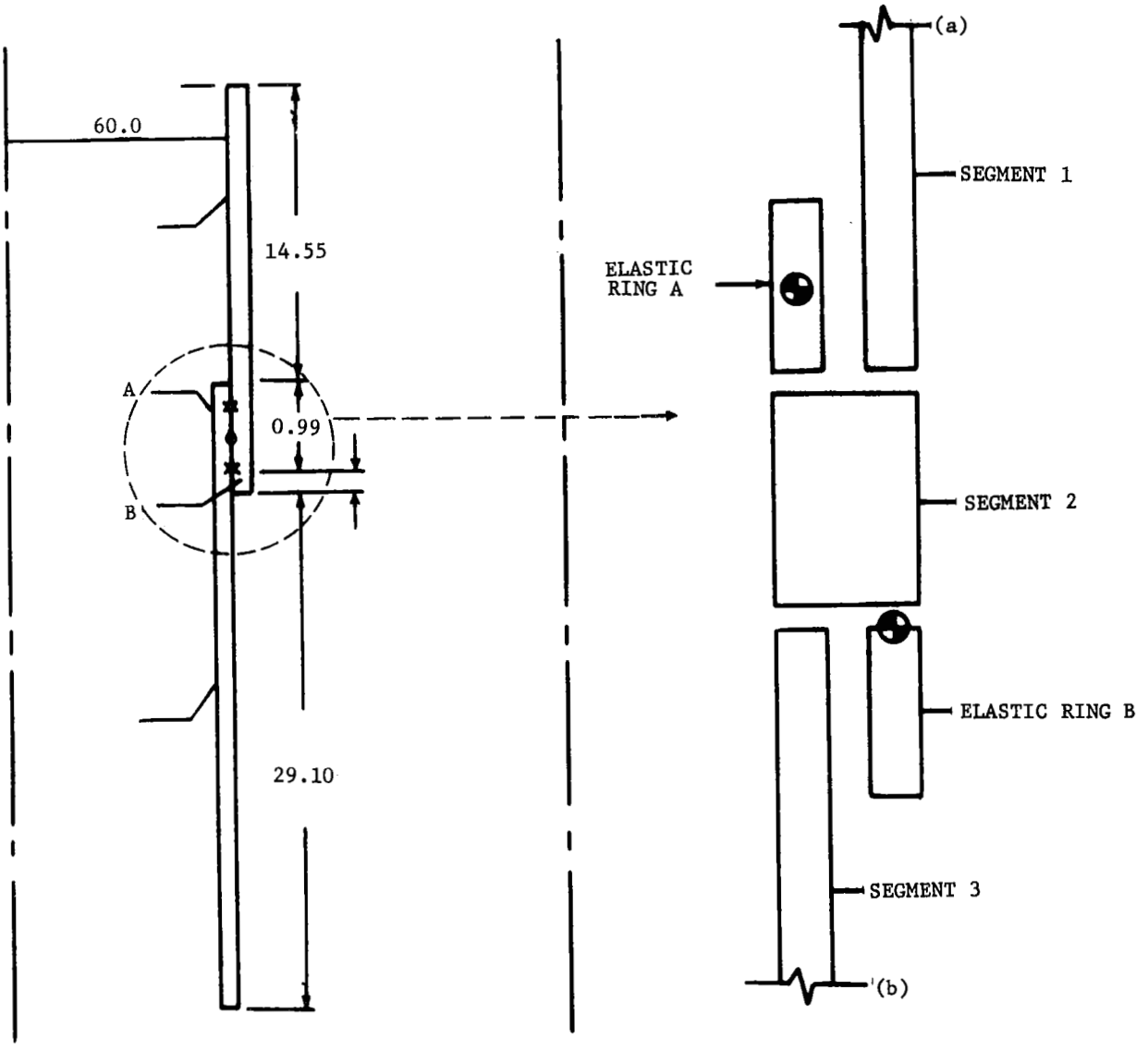
6. Finally, after the solutions have converged, the loading is incremented and the procedure is repeated starting at step 4.

1.4 Illustrative Problem

The present computer program (POWRS) was used to determine the post-wrinkling behavior of a typical section, (around Station 783.44), of the Atlas missile. The cylindrical section is shown in Figure 1.4a. The section consists of two cylinders joined together by an overlap splice joint. The model for this structure is shown in Figure 1.4b. Basically, the model consists of three shell segments and two elastic rings joined to the cylinders at point (c) and (d).

In determining the mathematical model for this structure, it was necessary to make a number of assumptions concerning the short cylinders A and B (see Figure 1.4a). Both cylinders were short enough so that they could be represented as elastic rings. Ring stiffness coefficients for these cylinders were obtained using the expressions given by Cohen, (Reference 17). However, when loaded, the two cylinders behave in different manners. Due to the external loads, cylinder A separates from the outside cylinder (segment 1), but cylinder B remains in contact with segment 3. The effect is that the forces acting on cylinder A are applied at discontinuity (c) which is offset from its c.g., but the resultant forces applied to cylinder B pass close to its c.g. To account for this difference, it was assumed that the c.g. of cylinder B was located at discontinuity (d), and the c.g. of cylinder A was taken as its geometric location. Although other mathematical models for this problem may be determined, it was felt that the present model would most closely represent the local behavior of this section.

A total of 137 pivotal points were used in the mathematical model of the structure. Segment 1 was divided into 50 intervals, segment 2 had 15 intervals and segment 3 had 70 intervals. Smaller interval sizes were used near the discontinuity and boundary points because of the rapid variation of the solution in these areas.



1.4a) Actual Structure (inches)

1.4b) Mathematical Model

Figure 1.4 Atlas Section 783.44

The loading was identical to that of Reference 3. The internal pressure at this section was 31.70 p.s.i., the axisymmetric meridional load was 519 lb/in, and a bending moment from 0 to 10.2×10^6 in-lb was applied to the section.

The boundary conditions at point (a) corresponded to symmetry conditions. Boundary conditions at point (b) corresponded to a rigid ring which, prior to being loaded by a bending moment, was allowed to deform radially due to the pressure loading. The bending moment and axial load were applied to the rigid ring at point (b). A total of seven Fourier harmonics were used in this analysis (i.e., M = 0 thru M = 6).

An approximate analysis for predicting the overall behavior of the post-wrinkled Atlas missile was given by Peery (Reference 18). This analysis assumes that the external moment is resisted by a meridional force which has a "cos θ" variation in the unwrinkled part of the cross-section of the cylinder, and a constant meridional force equal to the critical compressive force

$$N_C = \frac{1}{\sqrt{3(1-\mu^2)}} \frac{Et^2}{r}$$

in the wrinkled area. Wrinkling of the cylindrical section is assumed to occur when the compressive meridional force equals N_C. For the present problem, this would occur at a bending moment of 6.75×10^6 in-lb. It was found from the tests of Reference 3, and the analysis given here, that this was a good representation of the way the cylinder behaved.

Figures 1.5 thru 1.9 show the circumferential variation of the meridional force in segment 1 for increasing values of the bending moment. These curves show the circumferential growth of the wrinkling angle as the load increases. Values of the wrinkling angle, determined by Peery (Reference 18), are also shown on each figure. This angle is determined from the equation

$$\frac{M}{P_1 r} = \frac{(\pi - \theta_w) + \sin\theta_w \cos\theta_w}{2[\sin\theta_w + (\pi - \theta_w)\cos\theta_w]}$$

where

$P_1 = 2\pi r(N_M + N_C)$

N_M = axisymmetric meridional force

Figures 1.10 thru 1.14 give the meridional variation of the circumferential force, N_θ, in segment 1, for three circumferential angles, θ. Since the circumferential force behaves similarily to the radial deformation, these curves reflect the growth of the deep wrinkles along the meridian and around the circumference of the shell. Theta equal to 0 corresponds to the maximum compressive force meridian.

Figures 1.15 thru 1.24 show the meridional and circumferential bending moments, in segment 1, (M_ϕ and M_θ, respectively) as a function of the meridional distance. These curves show the increase in the bending stress due to the deep wrinkles.

Meridional and circumferential stresses obtained from the present analysis and the test* of Reference 3, are shown in Figures 1.25 thru 1.30. The comparisons at intermediate values of the bending moment are quite good considering that at bending moments greater than 7.4×10^6 in-lb, a 5% error in the applied moment causes a 20% error in stresses. The discrepencey in the circumferential stress away from the joint at zero moment could not be explained. Theoretically, the stress should have been a pure membrane stress of

$$\sigma_\theta = \frac{PR}{t} = \frac{(30.69)(60)}{.017} = 108{,}000 \text{ p.s.i.}$$

and the low value given by the test must be attributed to experimental errors. The difference in results at high values of the bending moment were probably due to the nonlinearity of the material properties. The cylinders were made of 301 EH stainless steel which exhibits a large nonlinear stress-strain relationship above 160,000 psi. One can therefore expect that at bending moments greater than 8.5×10^6 in-lbs, the experimental results should give higher strains, and

* This data has not yet been published, and was obtained in a private communication from R. P. Miller.

therefore higher stresses, when the data is reduced using a linear stress-strain law. Another possible reason for some difference in analytical and experimental results is that 301 EH stainless steel has a different modulus of elasticity in the meridional and circumferential direction while the present analysis assumes an isotropic homogeneous material.

The analysis showed that the maximum stress occurred on the outside surface of segment 1 at a distance 1.7 inches from the discontinuity point (c). Figure 1.31 shows the analytical and experimental stresses at this point. The stresses at this point do become quite high, and thus the cylinder may indeed rupture before the collapse load is attained.

The radial deformations in the neighborhood of the overlap section are shown in Figures 1.32 and 1.33. Correlation of experimental and analytical results are good at intermediate moments. At higher moments the discrepancy is again probably due to material property nonlinearities.

Finally, Figure 1.34 gives the end shortening of the $\theta = 0$ meridian as a function of the applied bending moment. An estimate of the collapse load of the cylinder may be obtained from this curve by using the Southwell method. Plotting δ/M vs. δ is shown in Figure 1.34, and taking the inverse of the slope of the resulting curve, gives a collapse load of 13.0×10^6 in/lb. This value is only slightly below Peery's results which predicts that collapse occurs when the complete cylindrical cross-section is wrinkled (i.e., $\theta_w = \pi$), and yields a collapse moment of 13.5×10^6 in/lb.

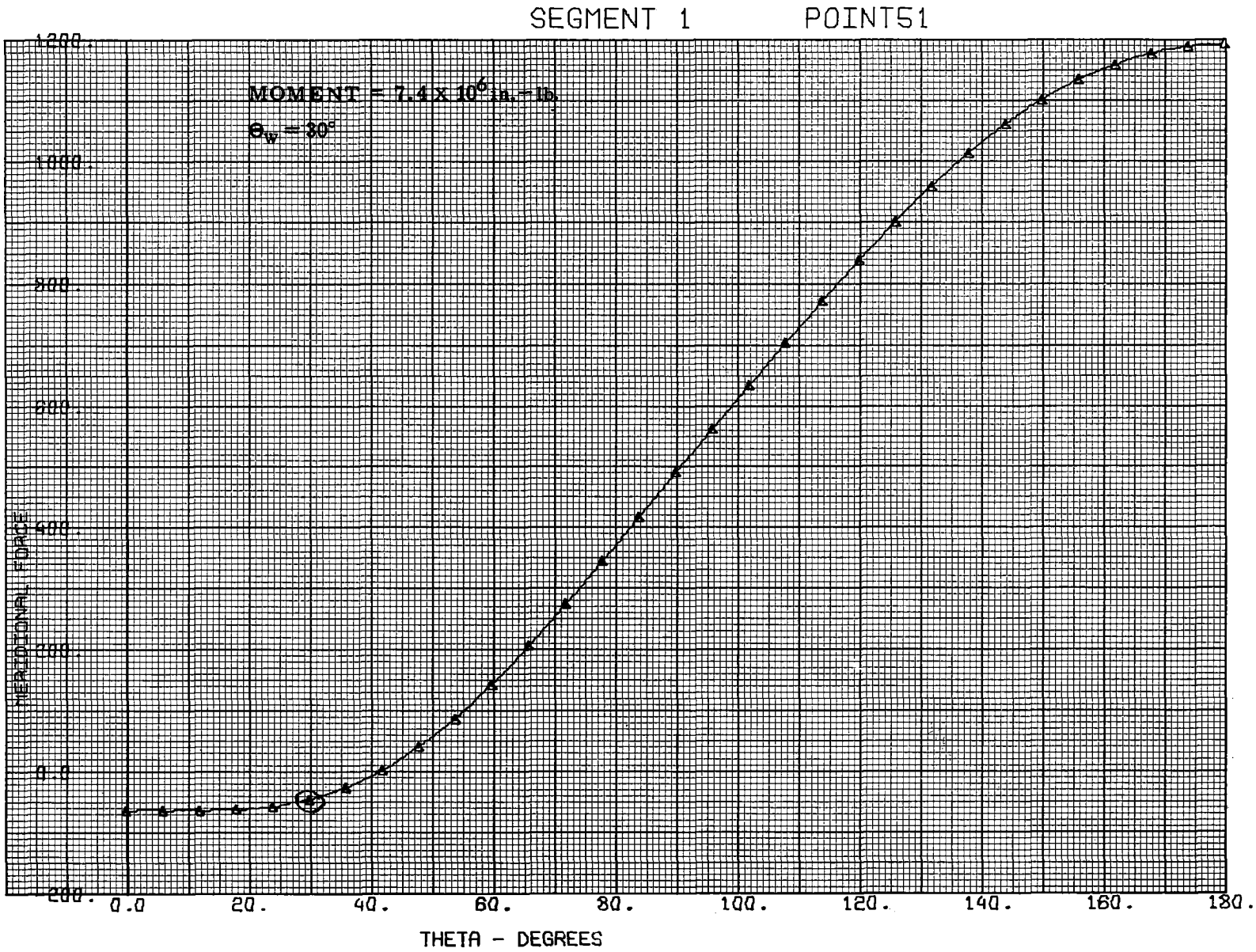


Figure 1.5 Meridional Force Versus Theta

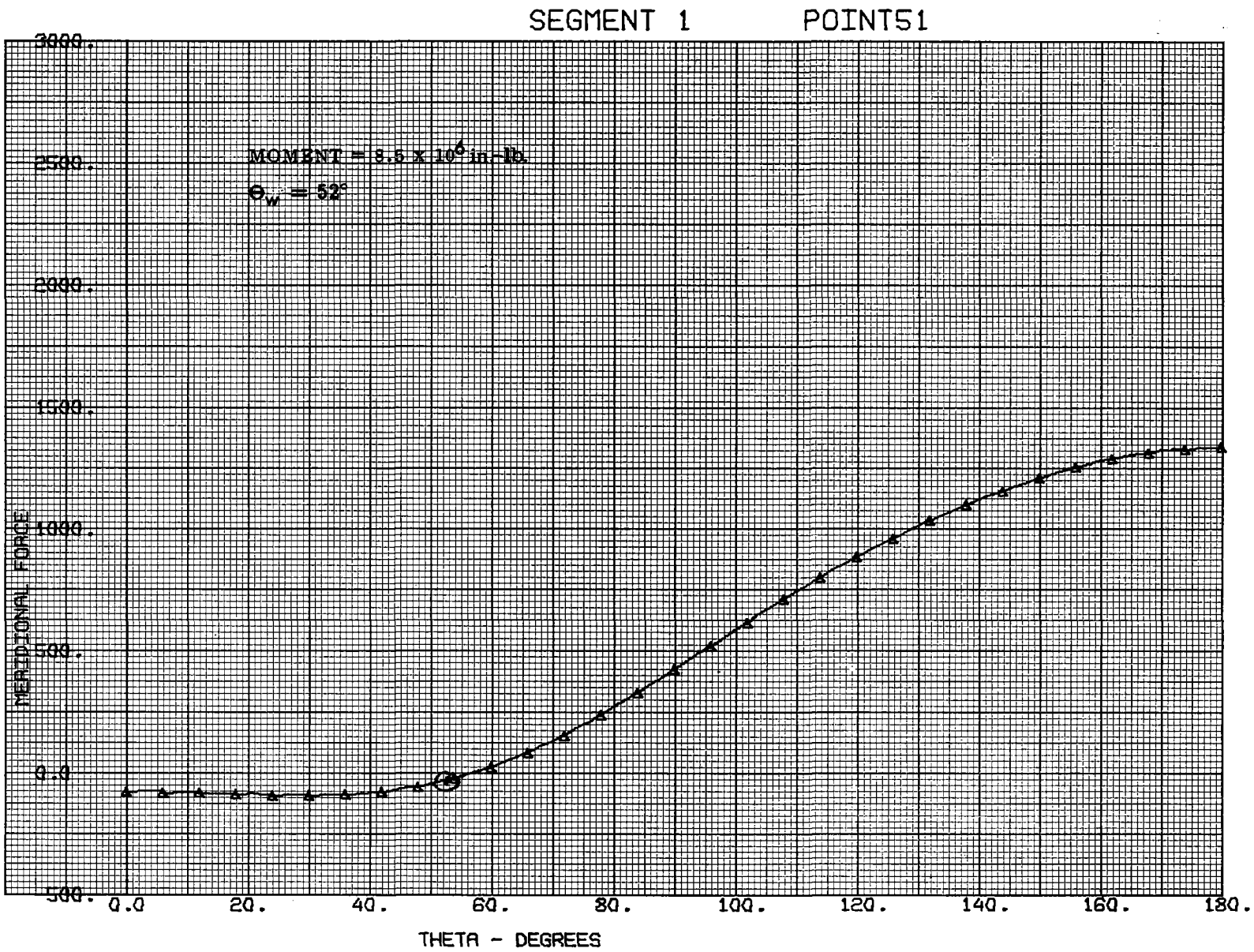


Figure 1.6 Meridional Force Versus Theta

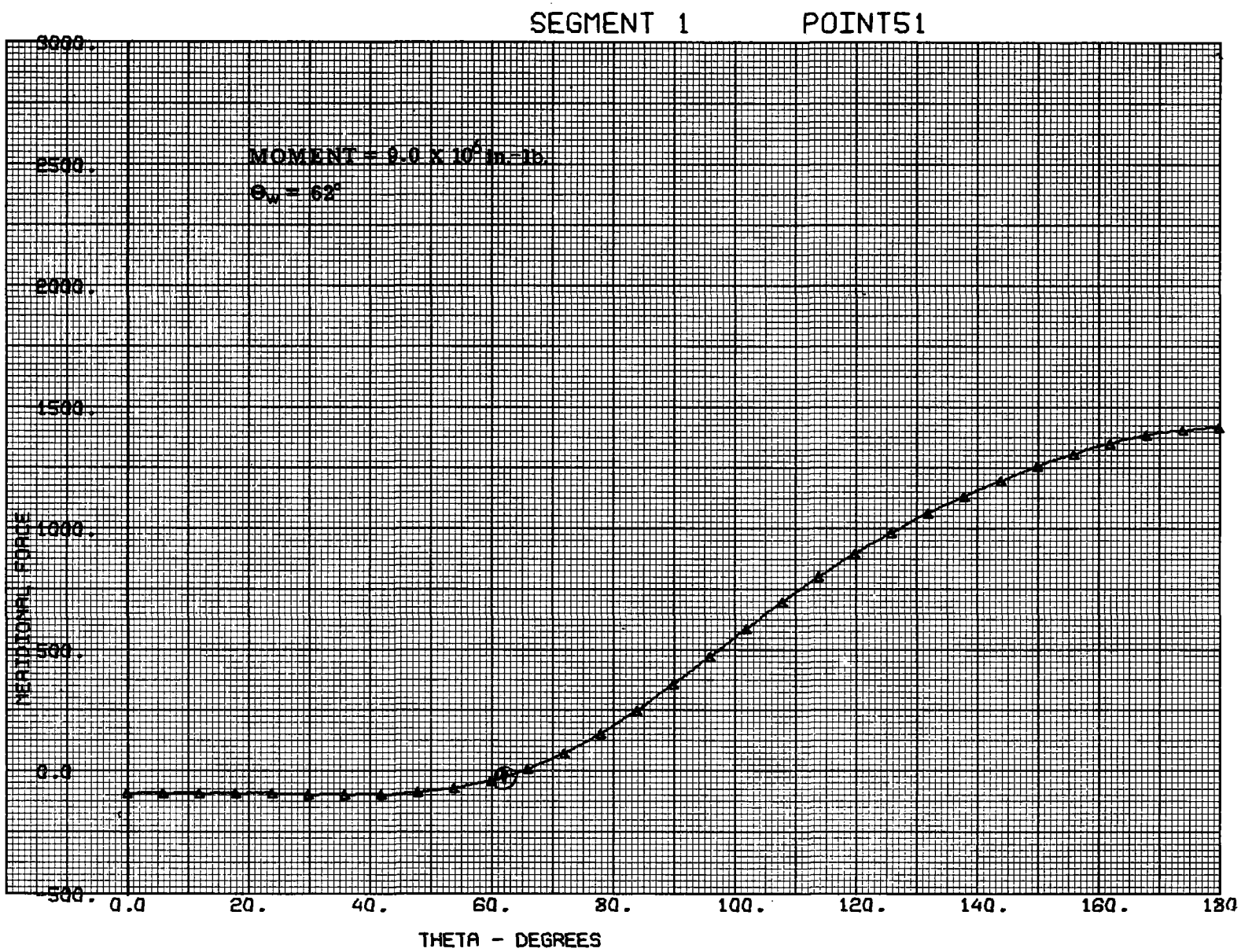


Figure 1.7 Meridional Force Versus Theta

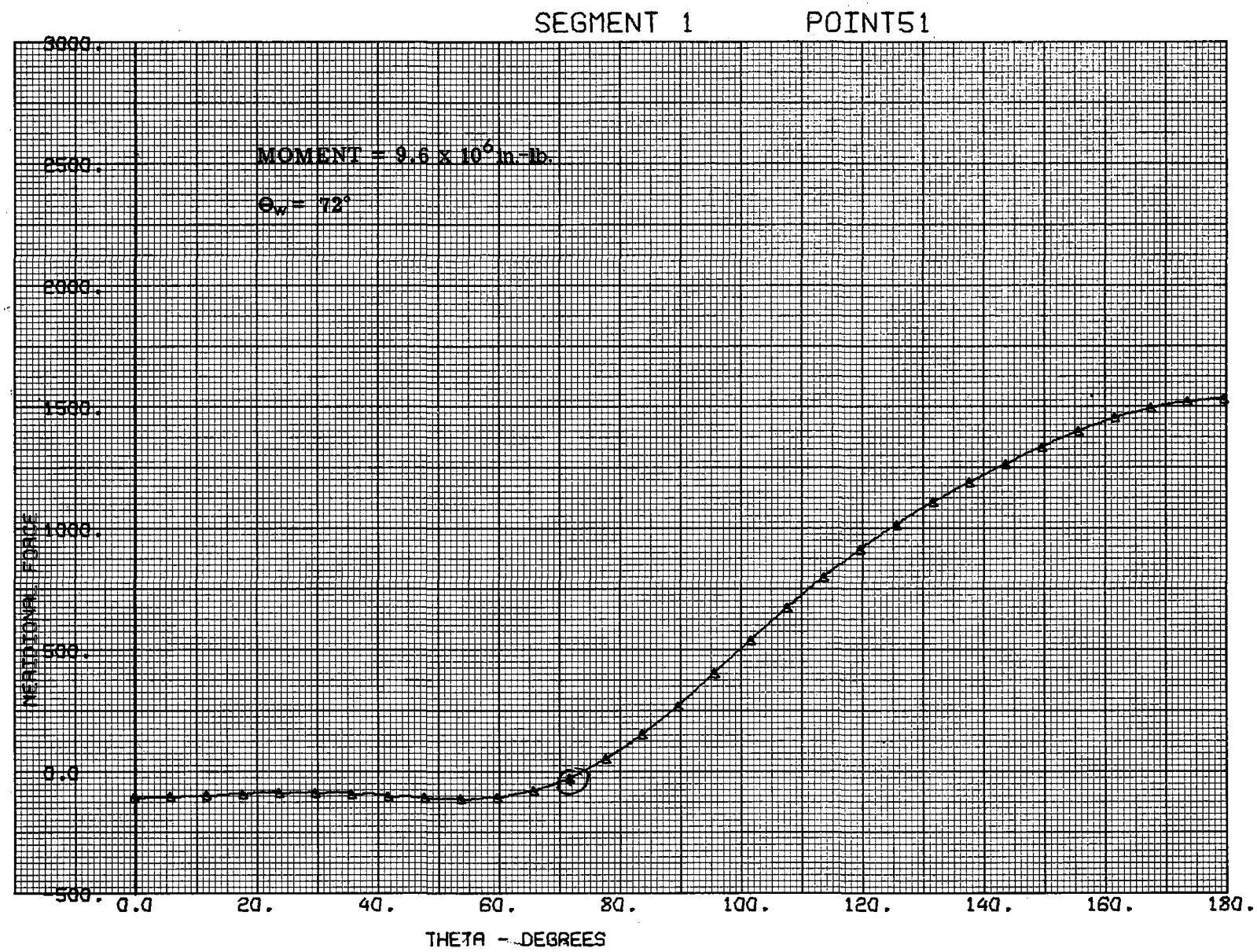


Figure 1.8 Meridional Force Versus Theta

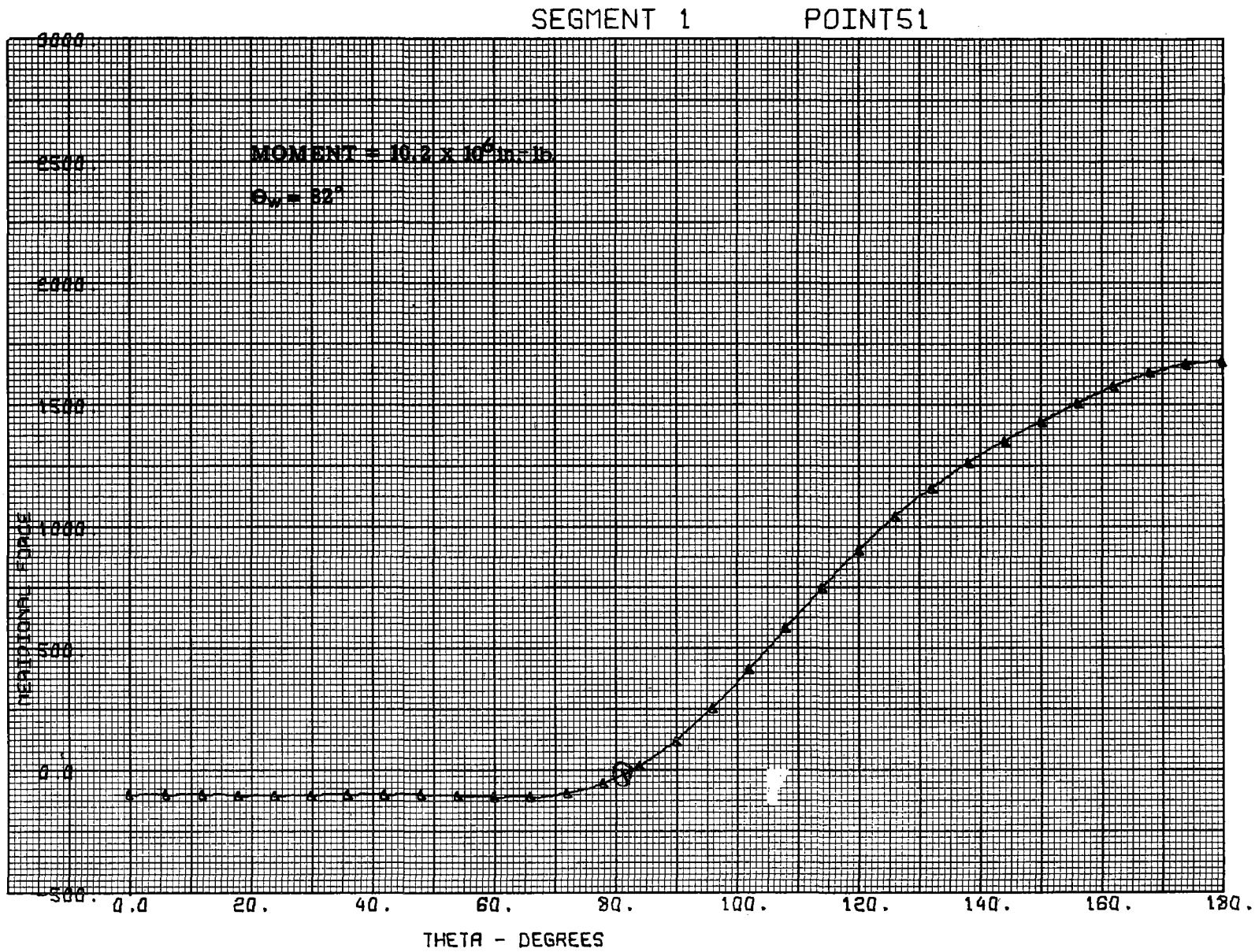


Figure 1.9 Meridional Force Versus Theta

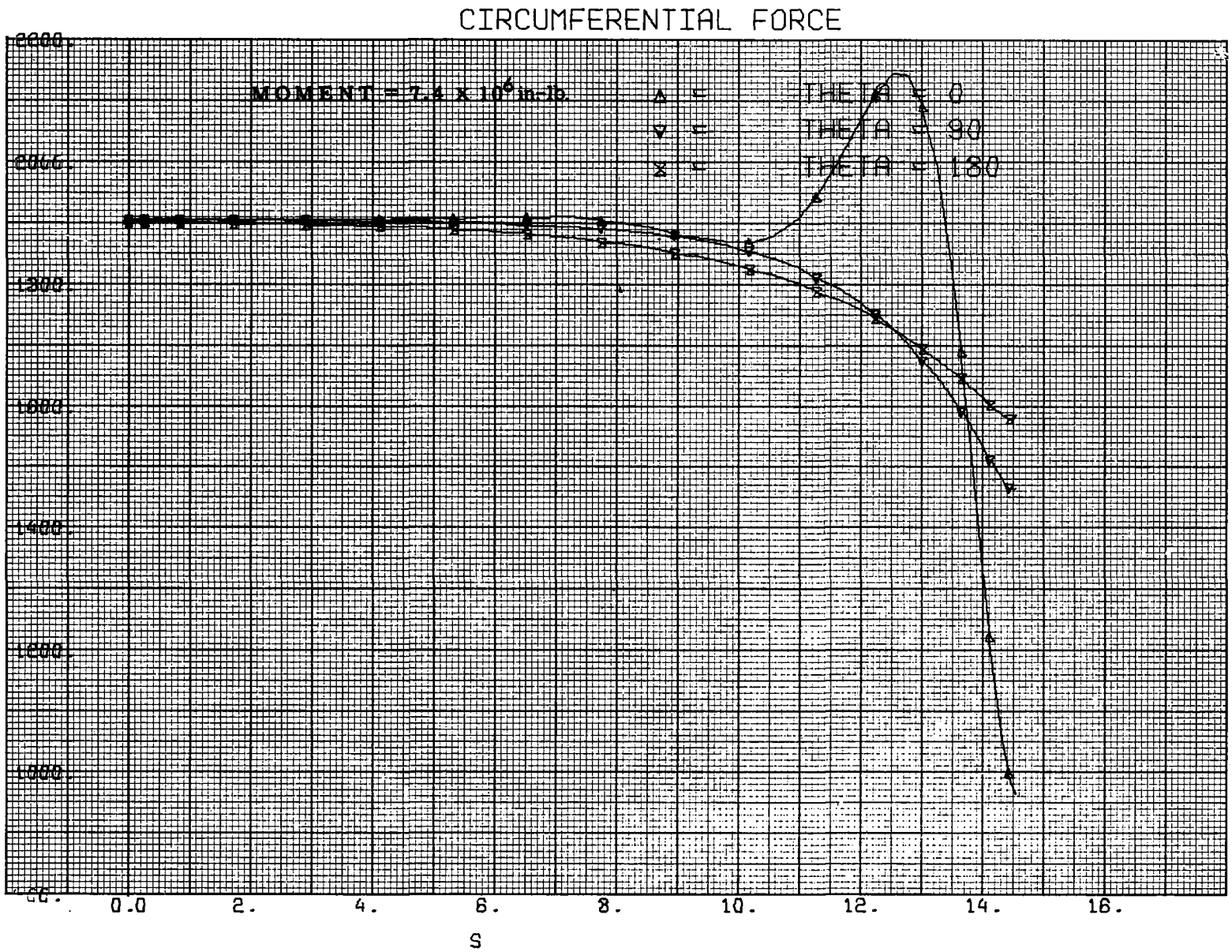


Figure 1.10 Circumferential Force Versus S (Segment 1)

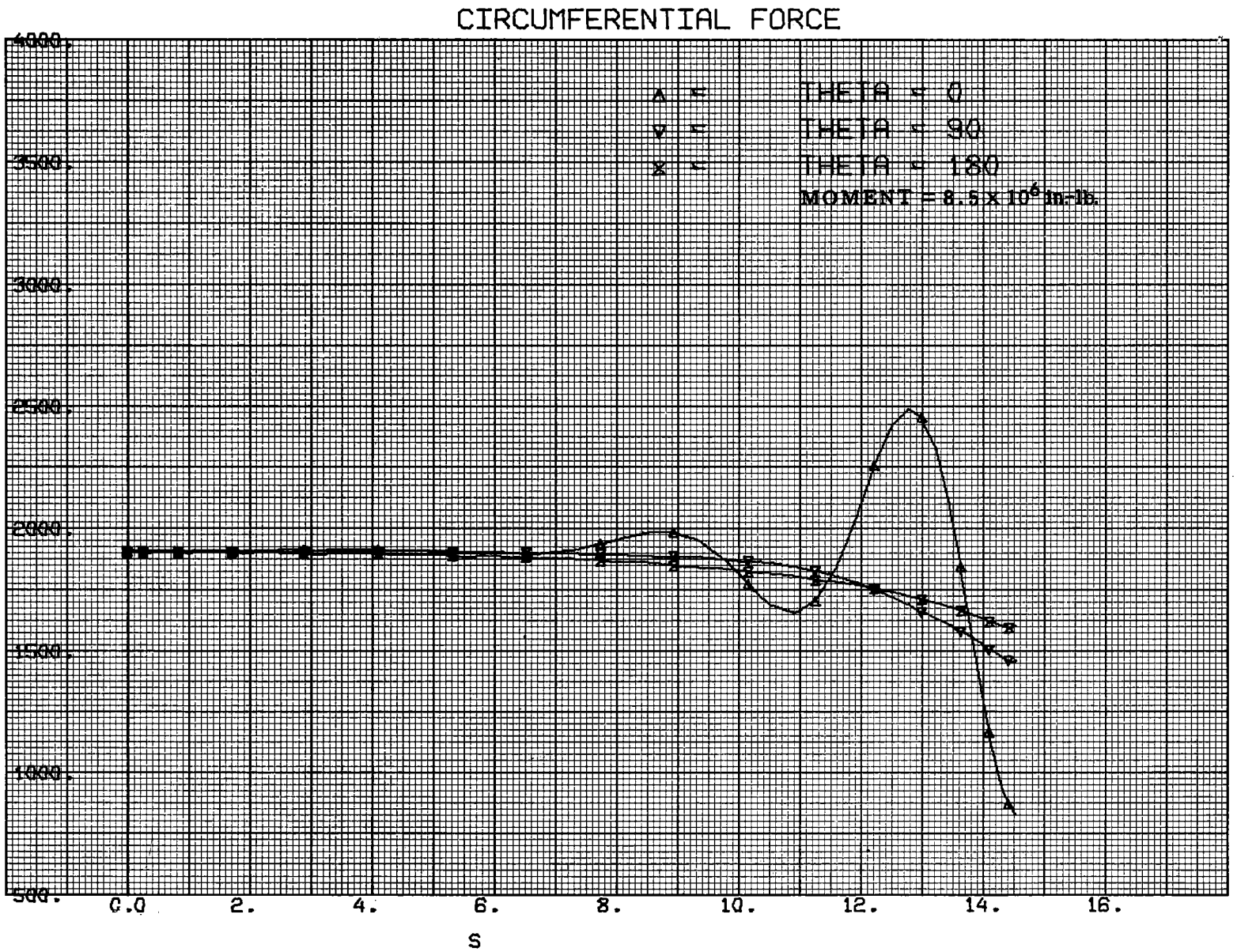


Figure 1.11 Circumferential Force Versus S (Segment 1)

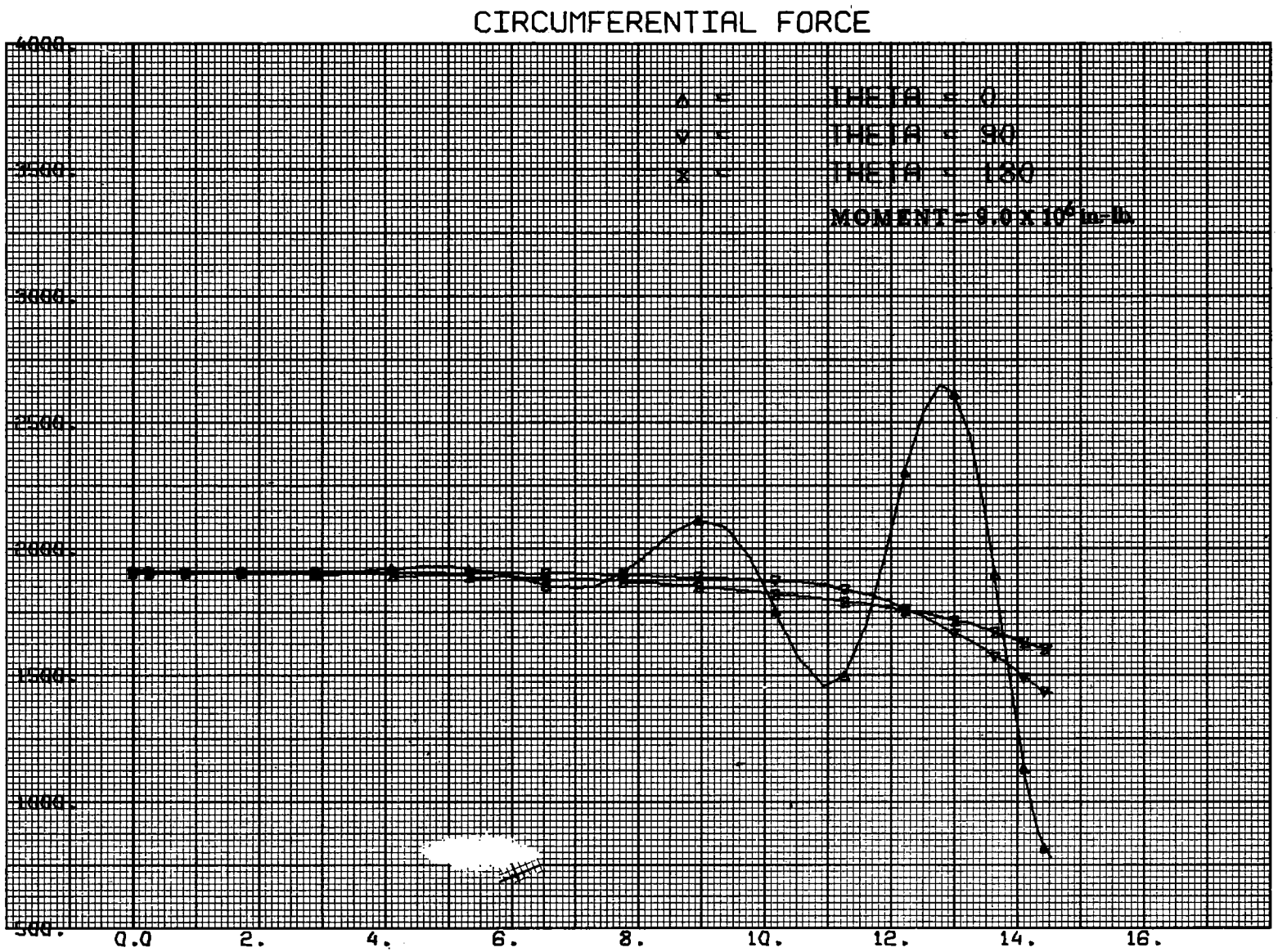


Figure 1.12 Circumferential Force Versus S (Segment 1)

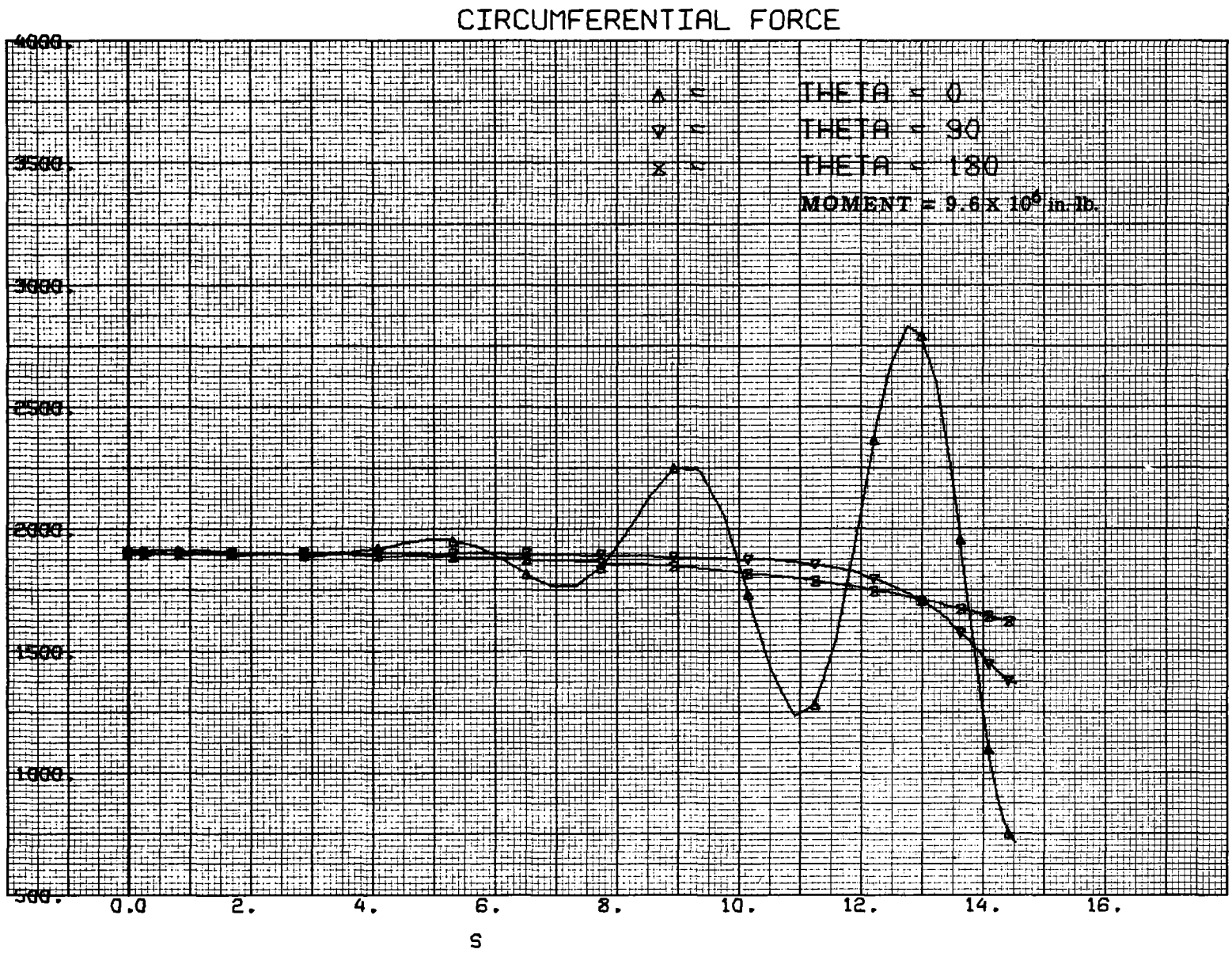


Figure 1.13 Circumferential Force Versus S (Segment 1)

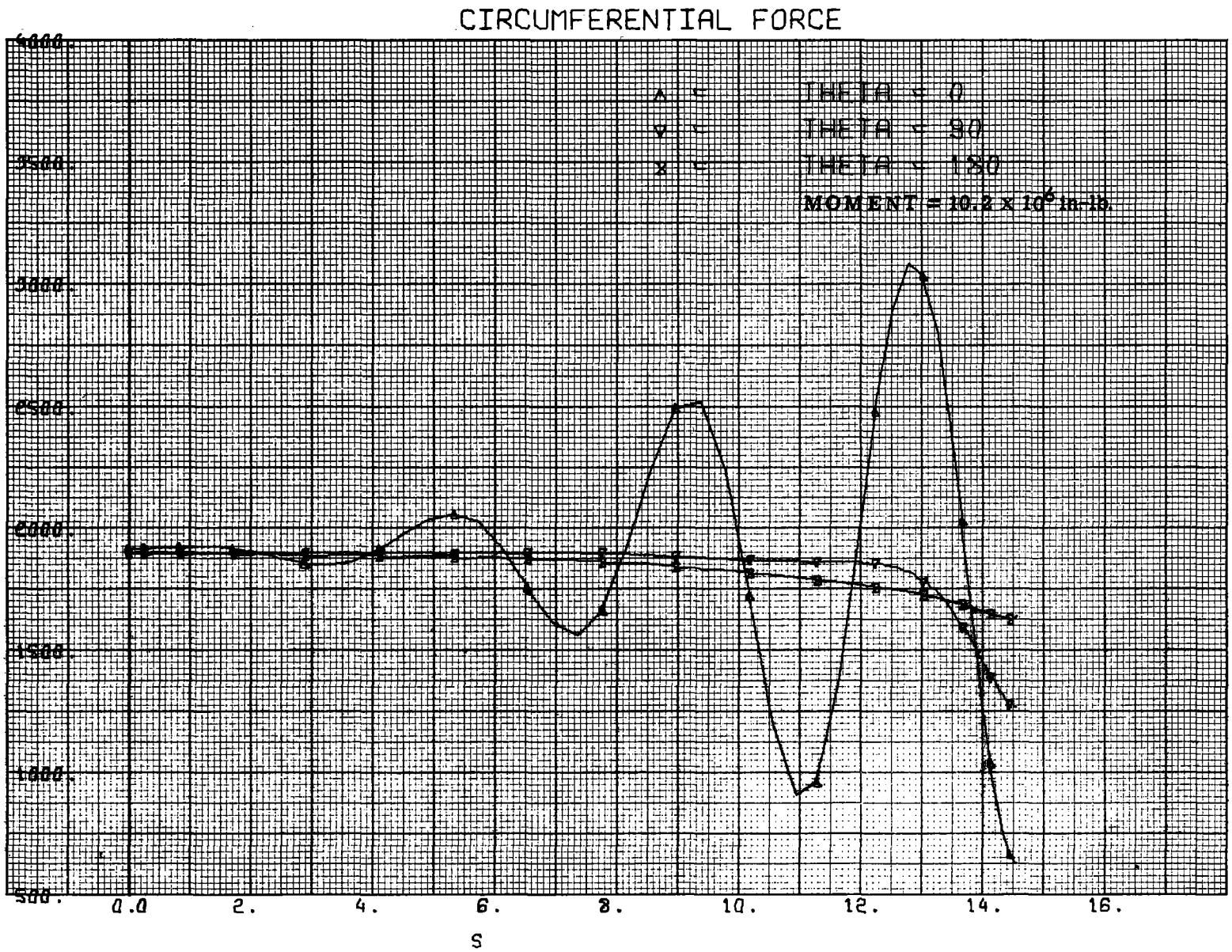


Figure 1.14 Circumferential Force Versus S (Segment 1)

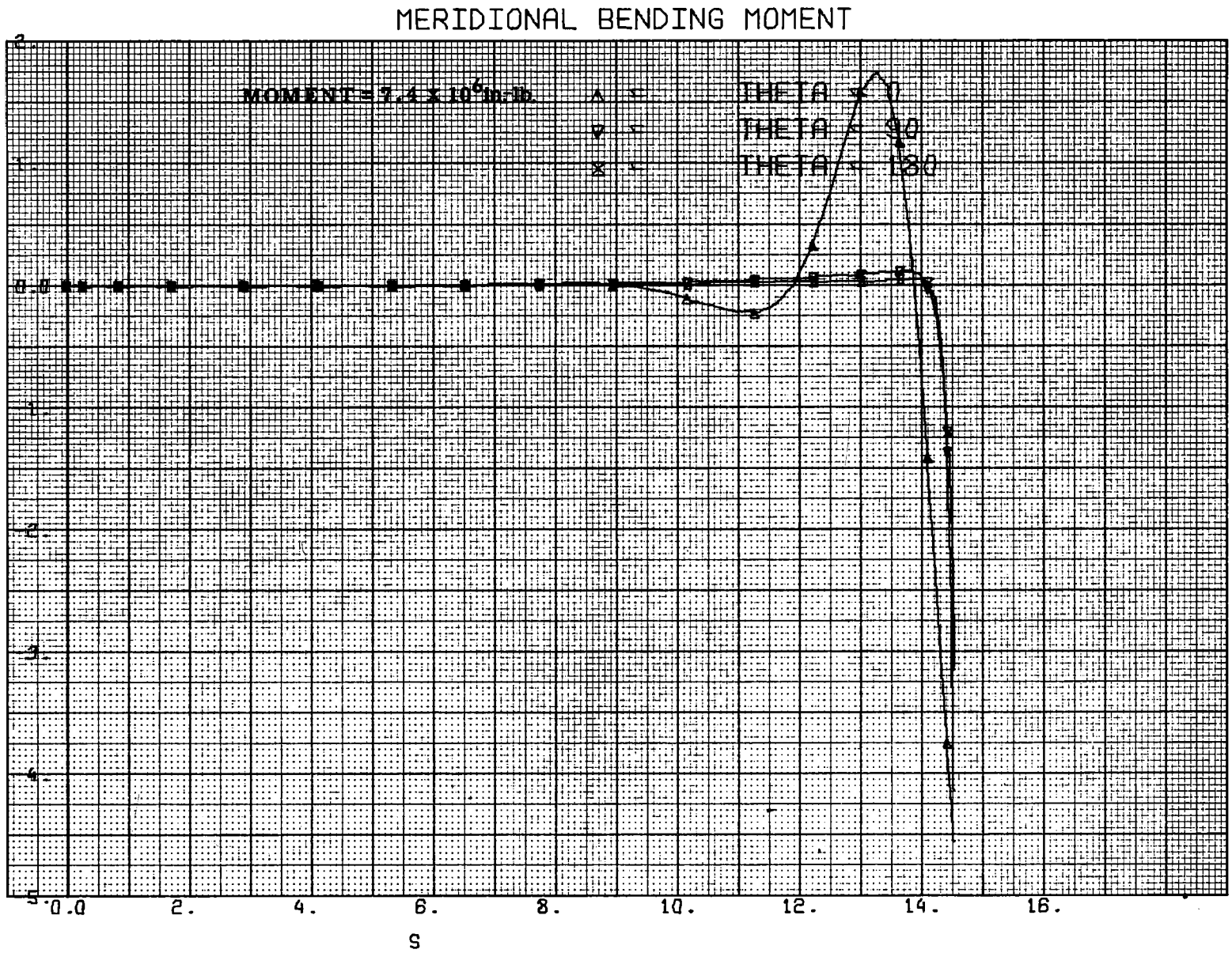


Figure 1.15 Meridional Bending Moment Versus S (Segment 1)

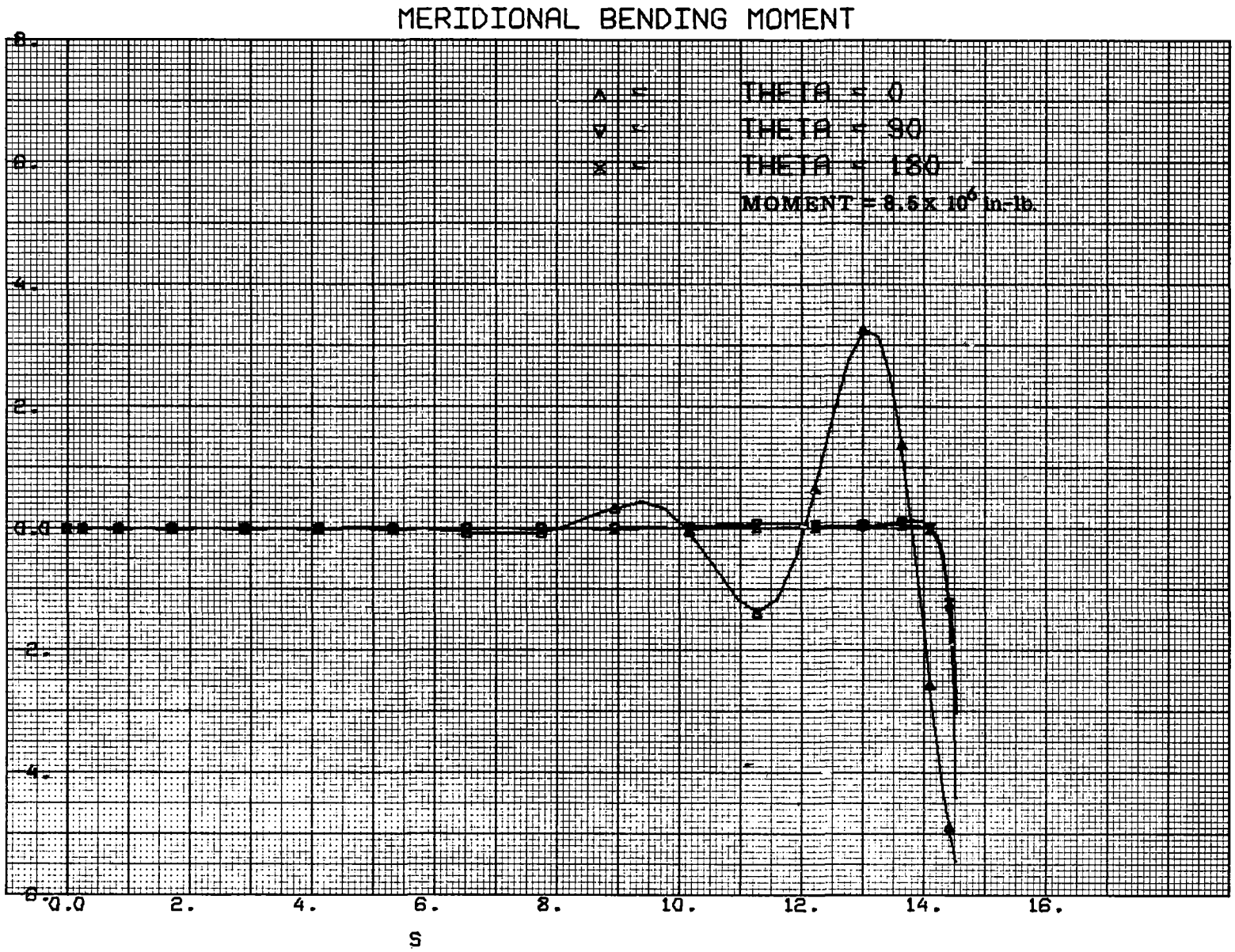


Figure 1.16 Meridional Bending Moment Versus S (Segment 1)

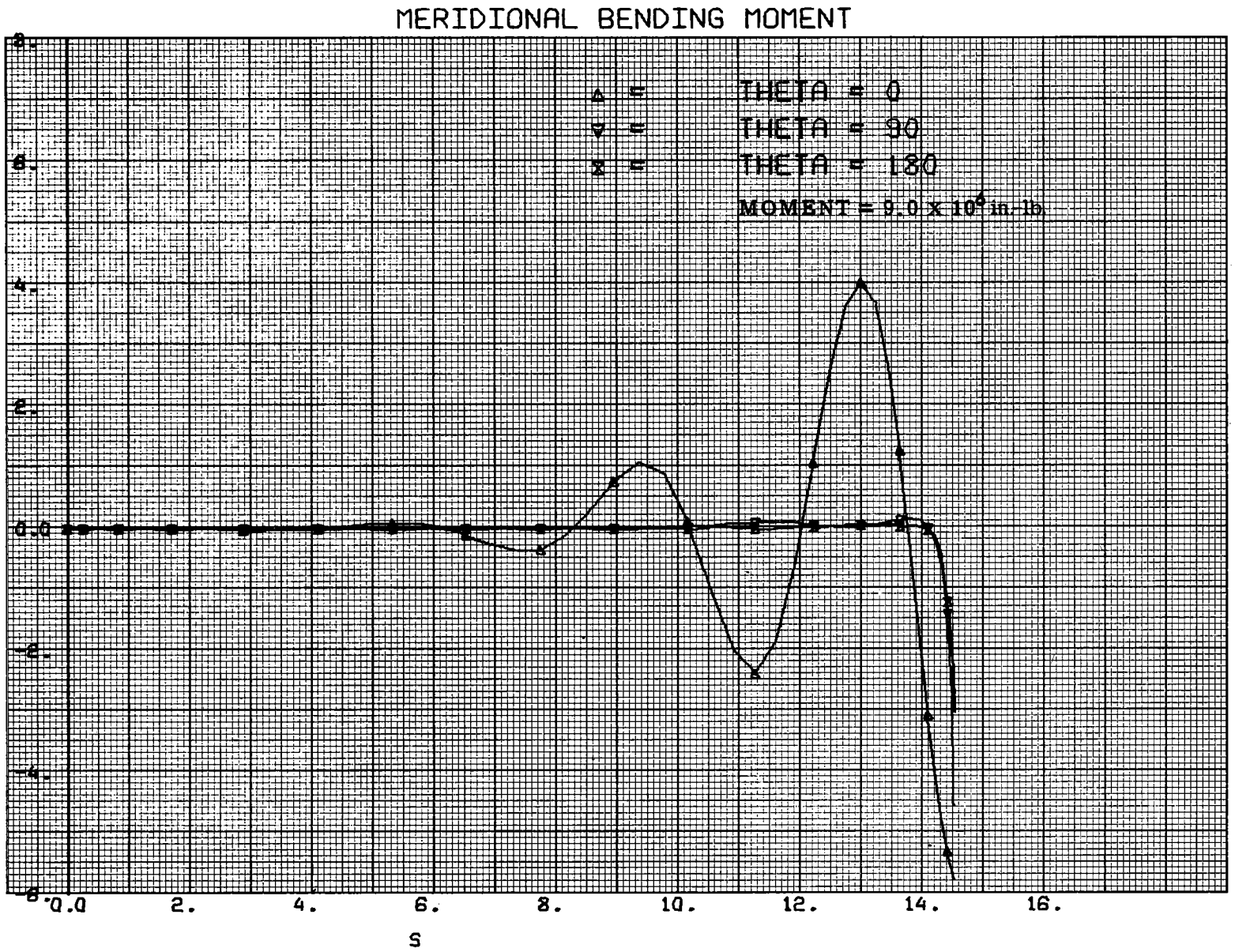


Figure 1.17 Meridional Bending Moment Versus S (Segment 1)

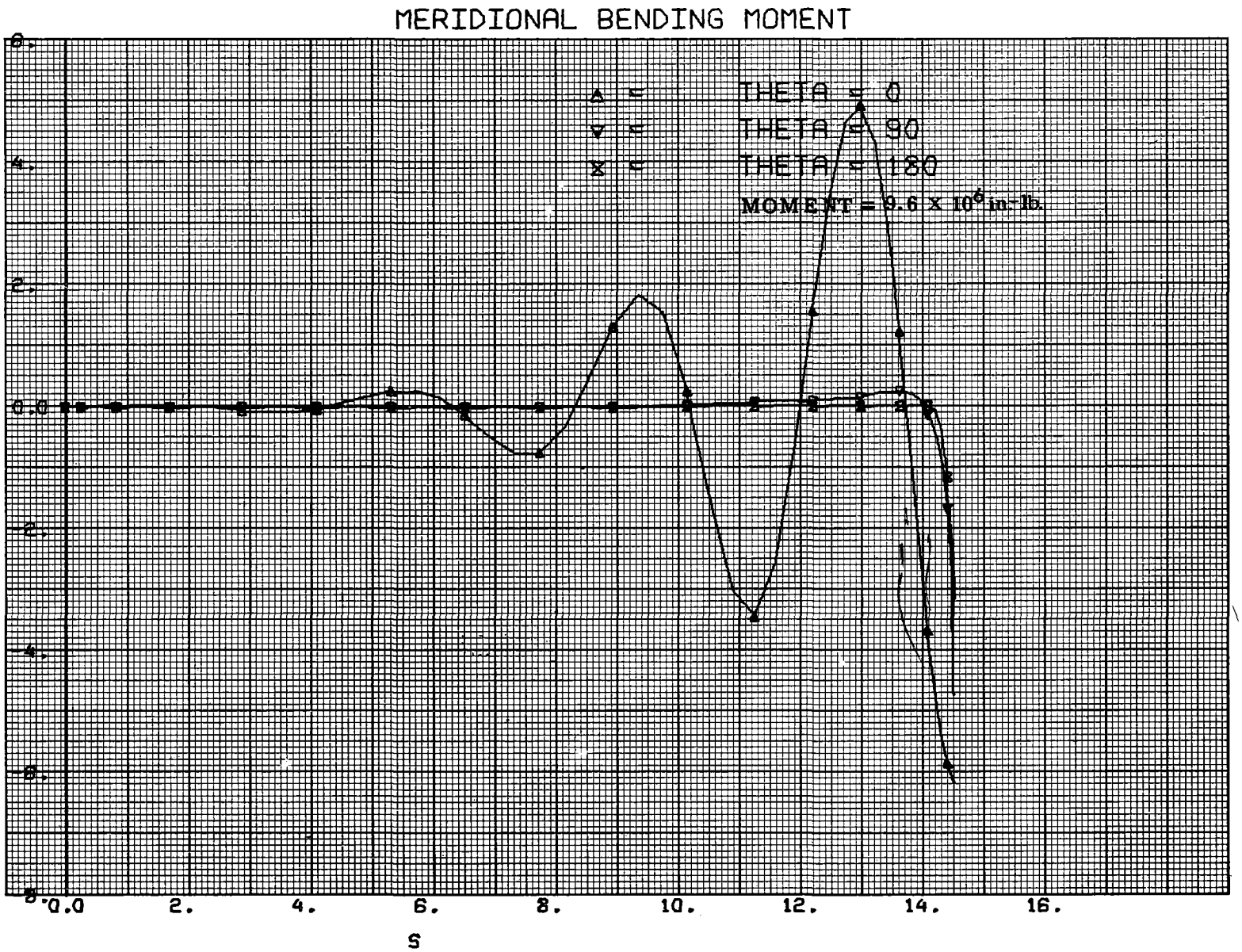


Figure 1.18 Meridional Bending Moment Versus S (Segment 1)

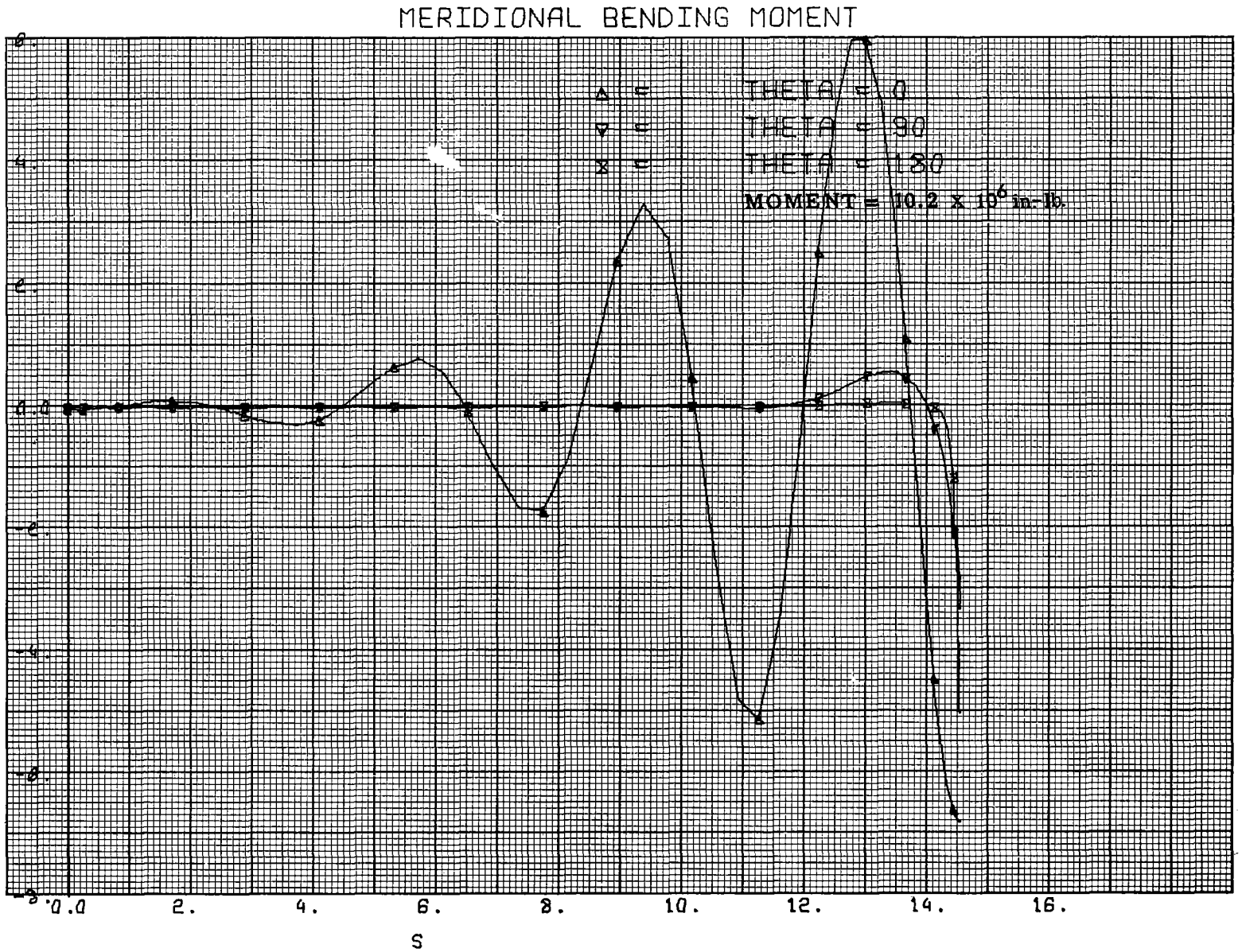


Figure 1.19 Meridional Bending Moment Versus S (Segment 1)

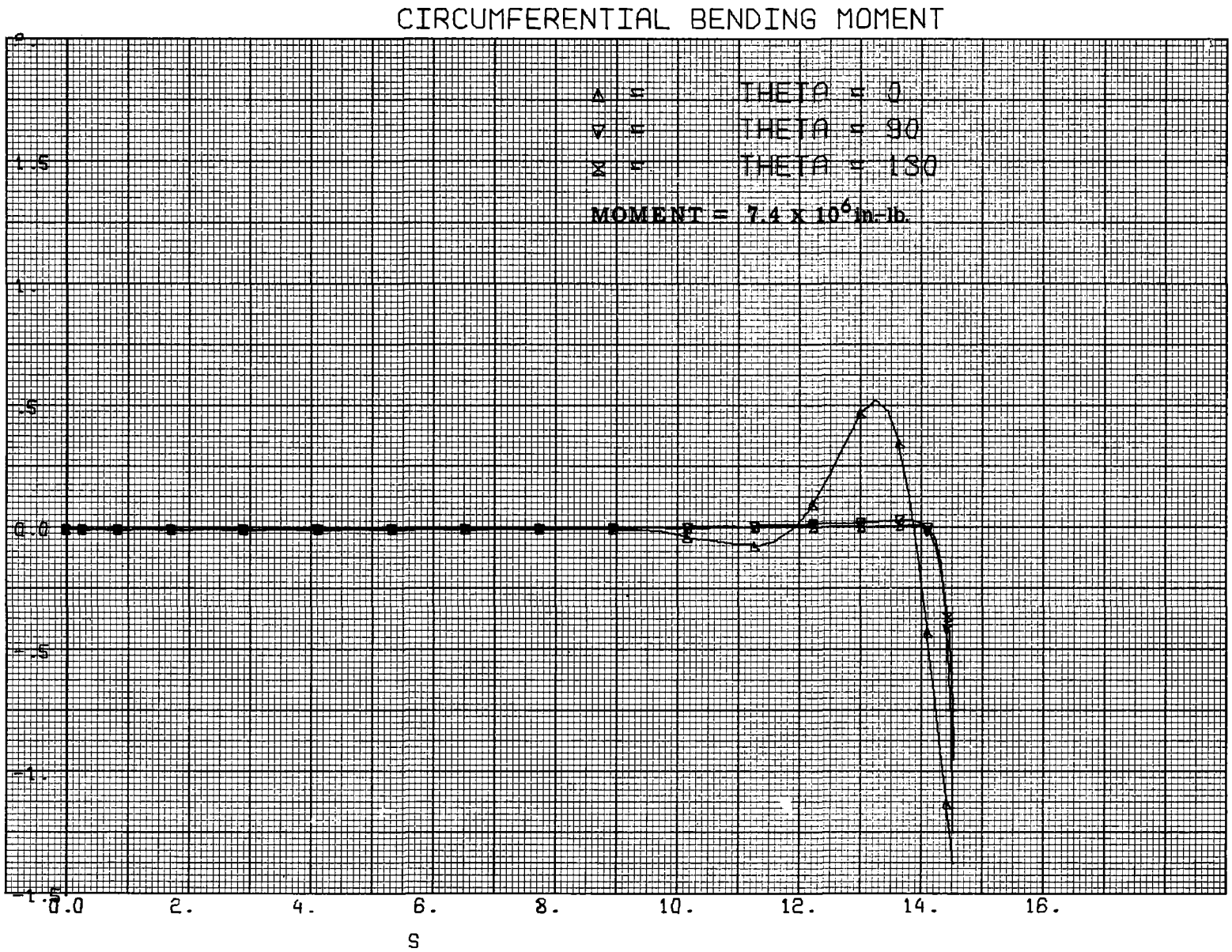


Figure 1.20 Circumferential Bending Moment Versus S (Segment 1)

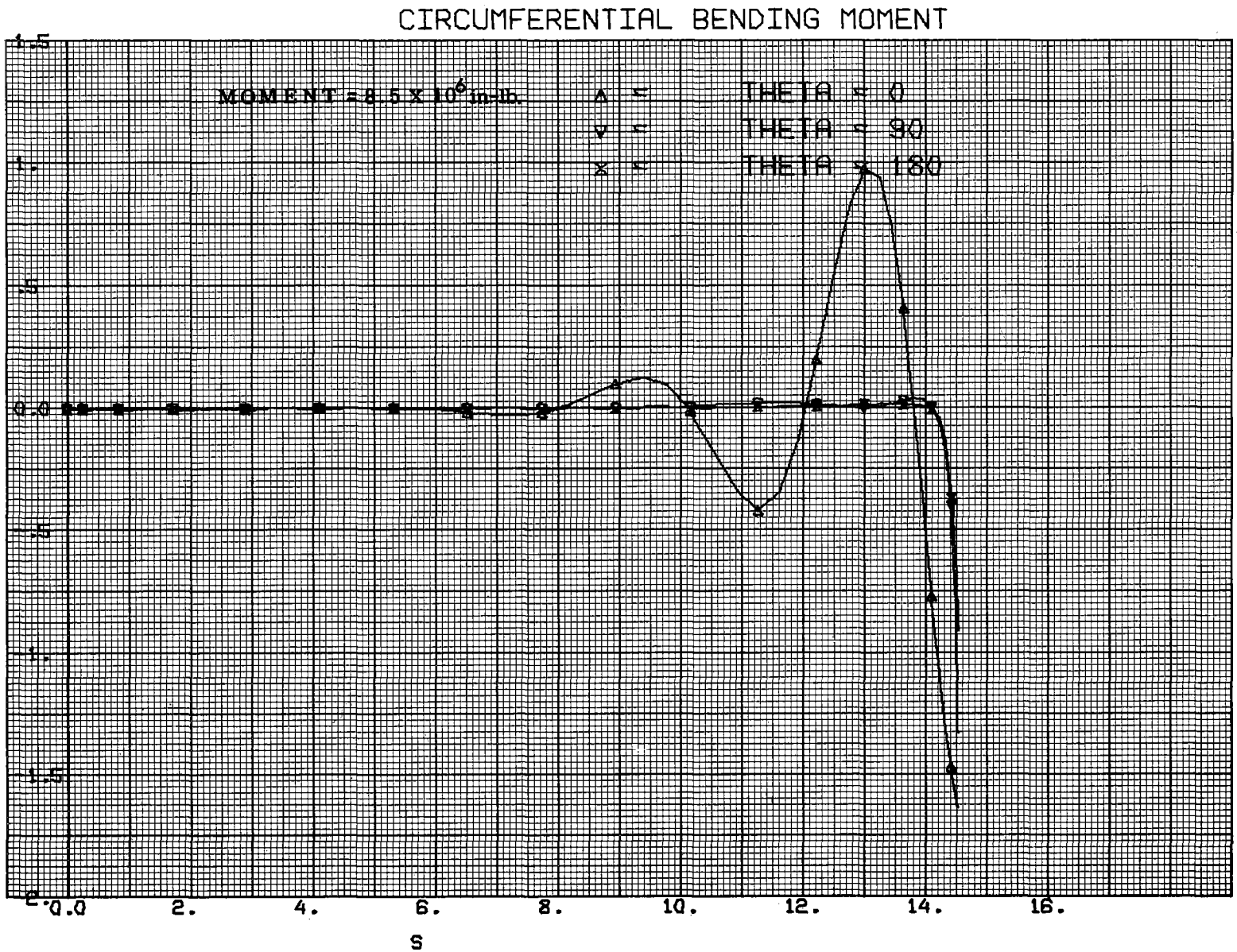


Figure 1.21 Circumferential Bending Moment Versus S (Segment 1)

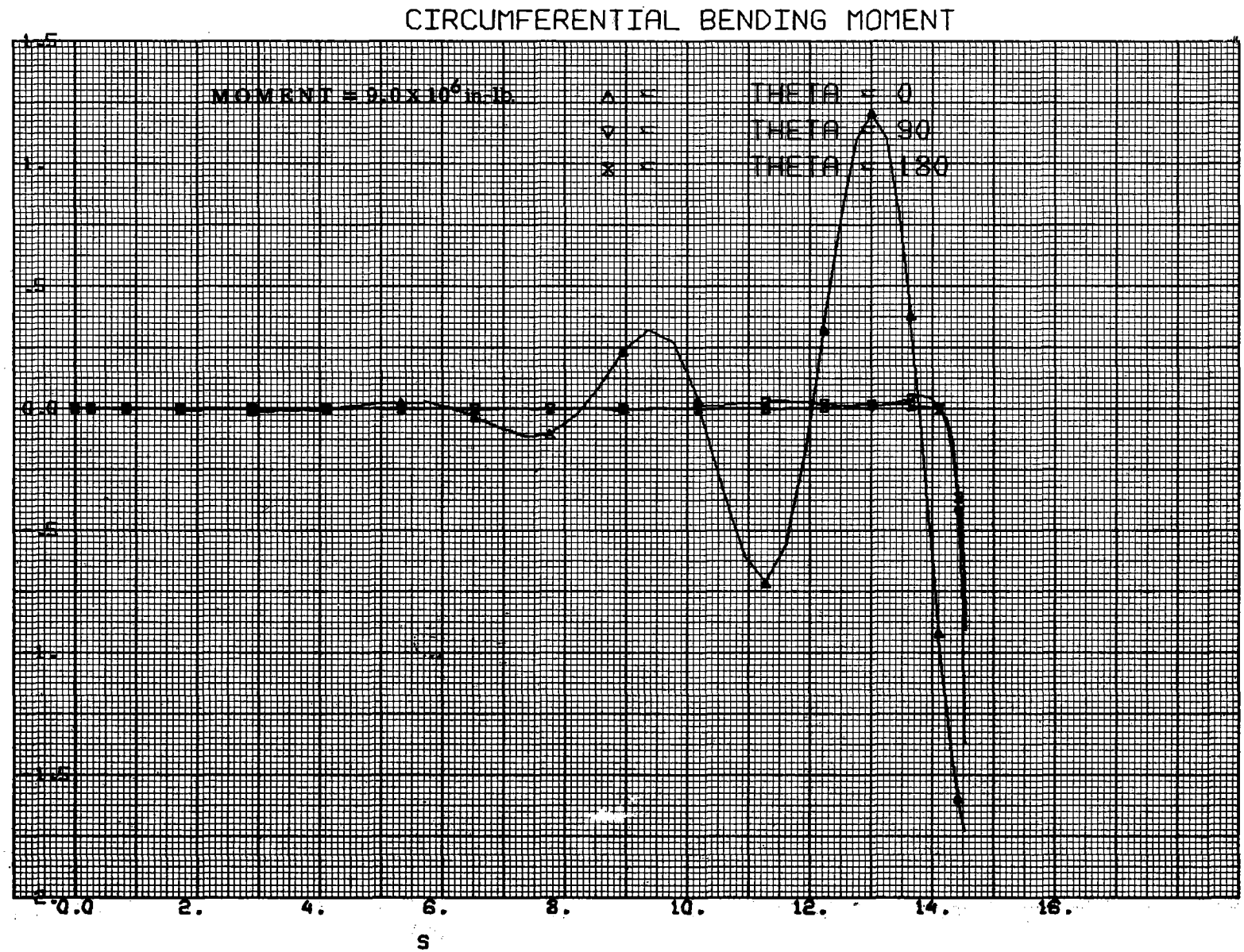


Figure 1.22 Circumferential Bending Moment Versus S (Segment 1)

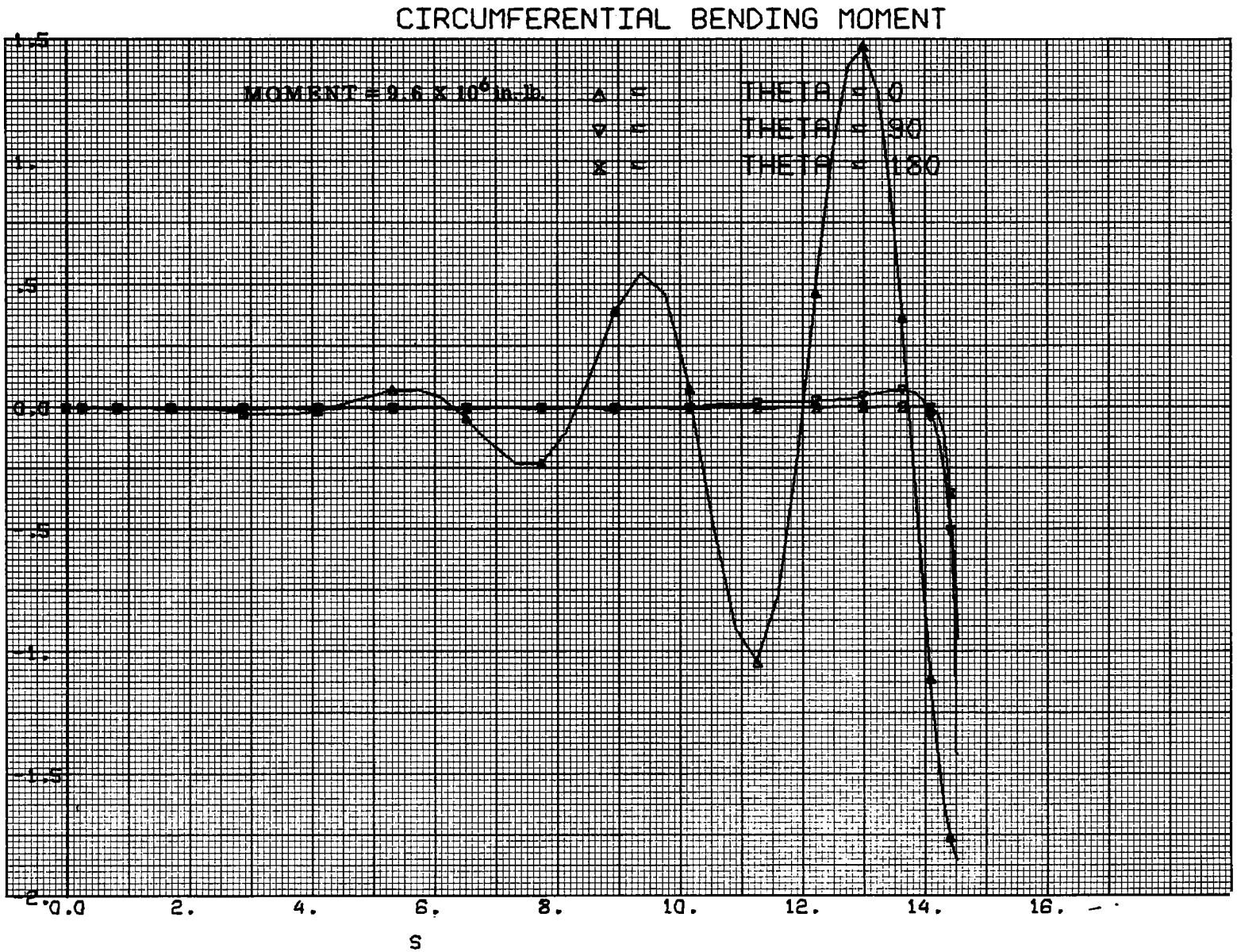


Figure 1.23 Circumferential Bending Moment Versus S (Segment 1)

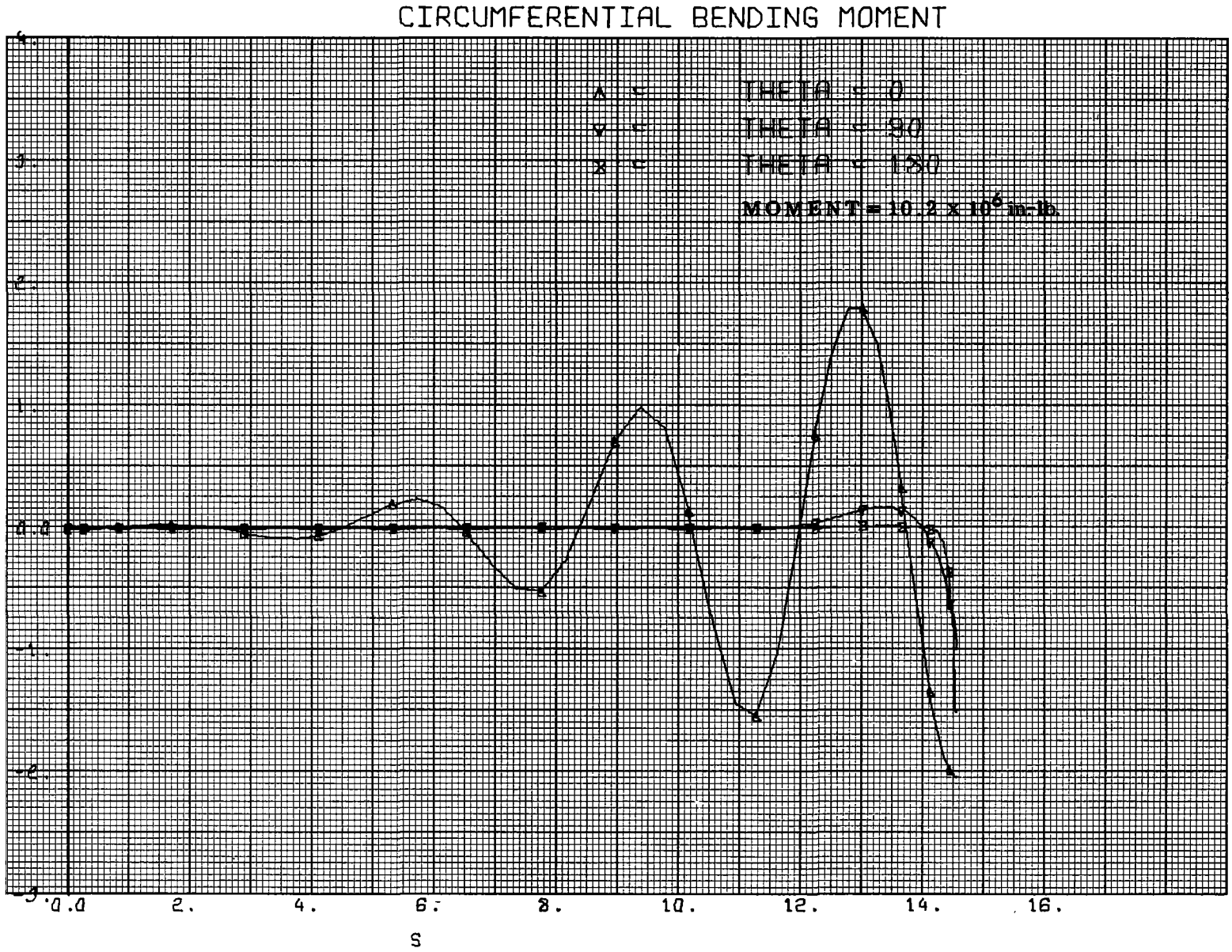


Figure 1.24 Circumferential Bending Moment Versus S (Segment 1)

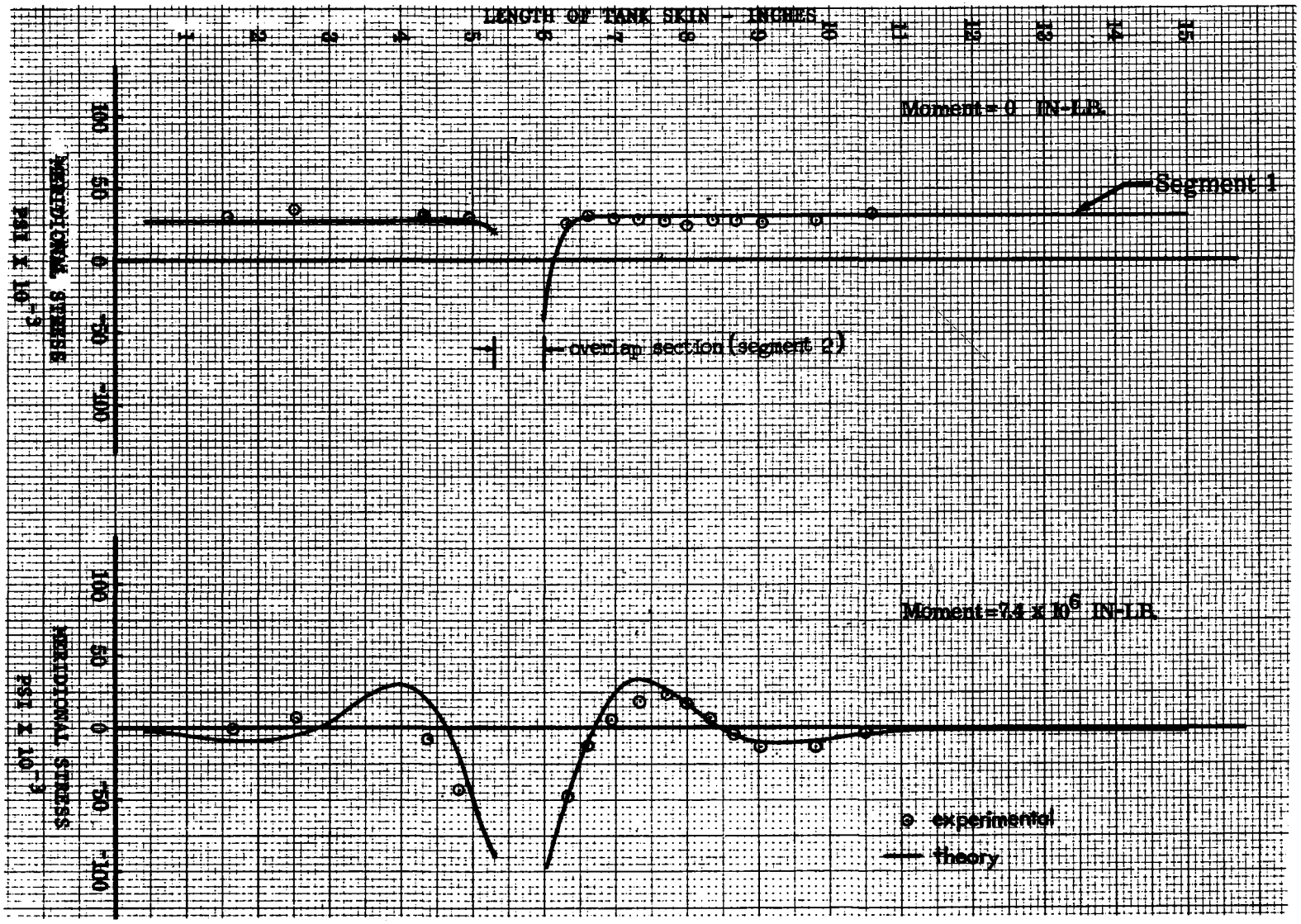


Figure 1.25 Meridional Stress Versus S for θ = 0

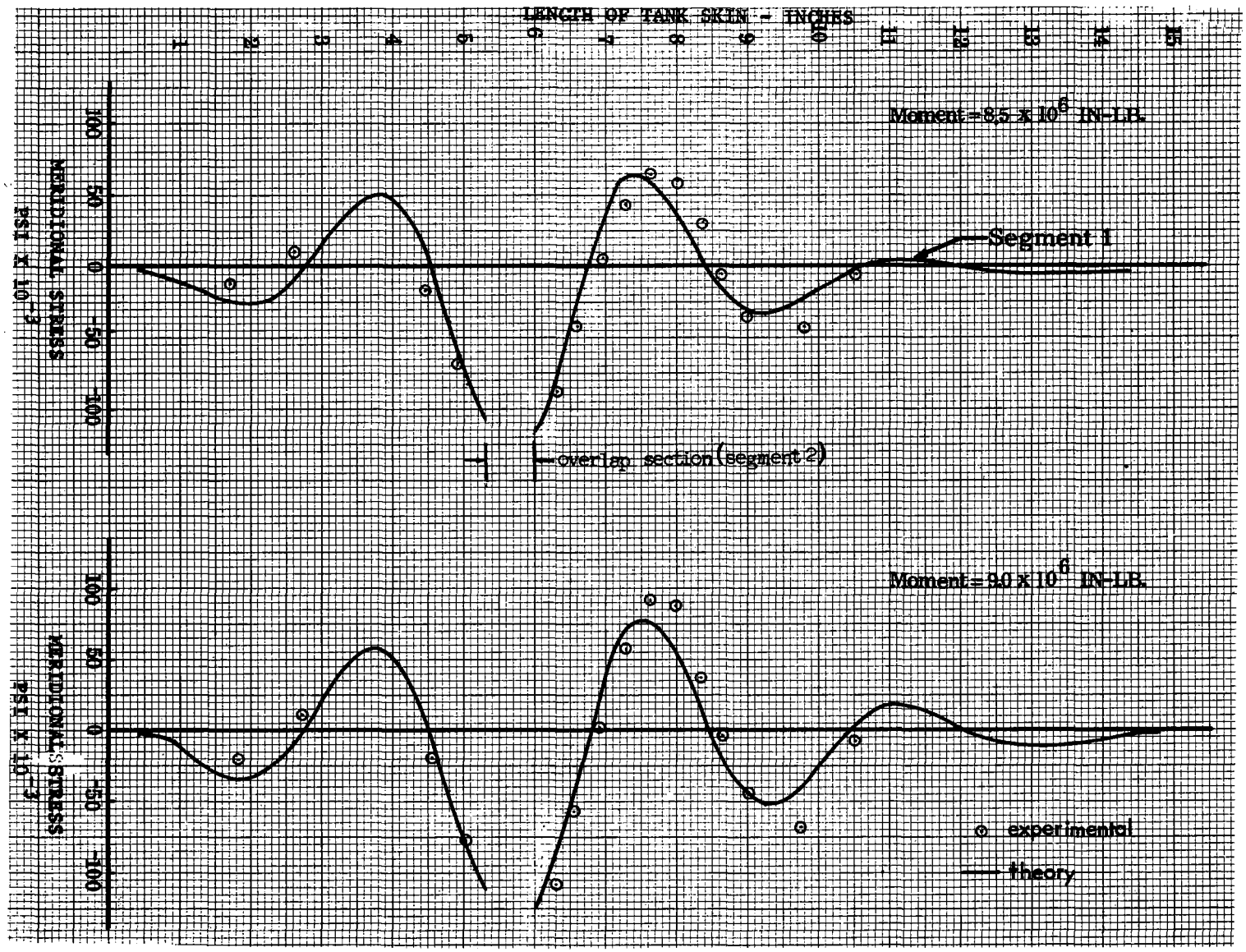


Figure 1.26 Meridional Stress Versus S for $\theta = 0$

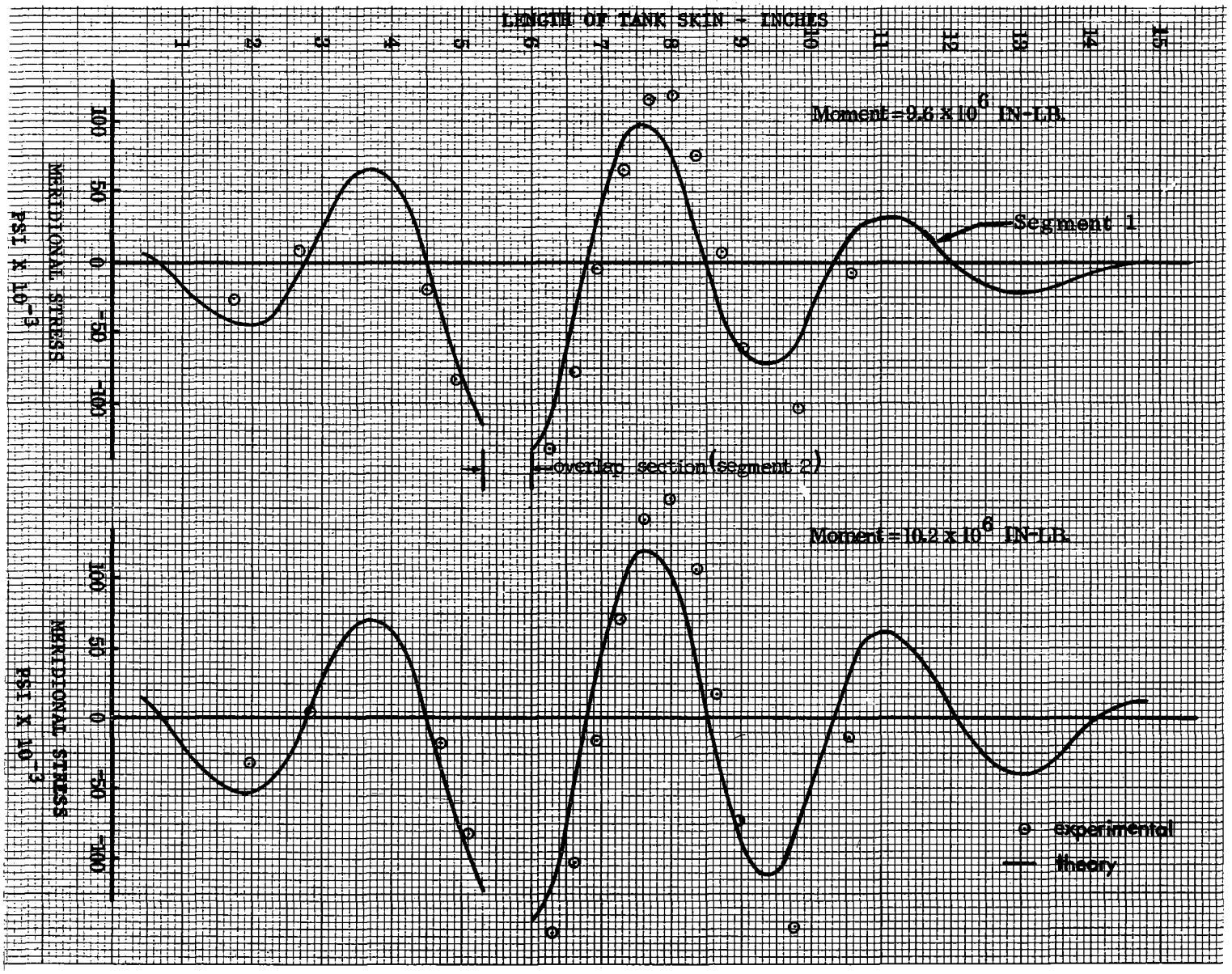


Figure 1.27 Meridional Stress Versus S for $\theta = 0$

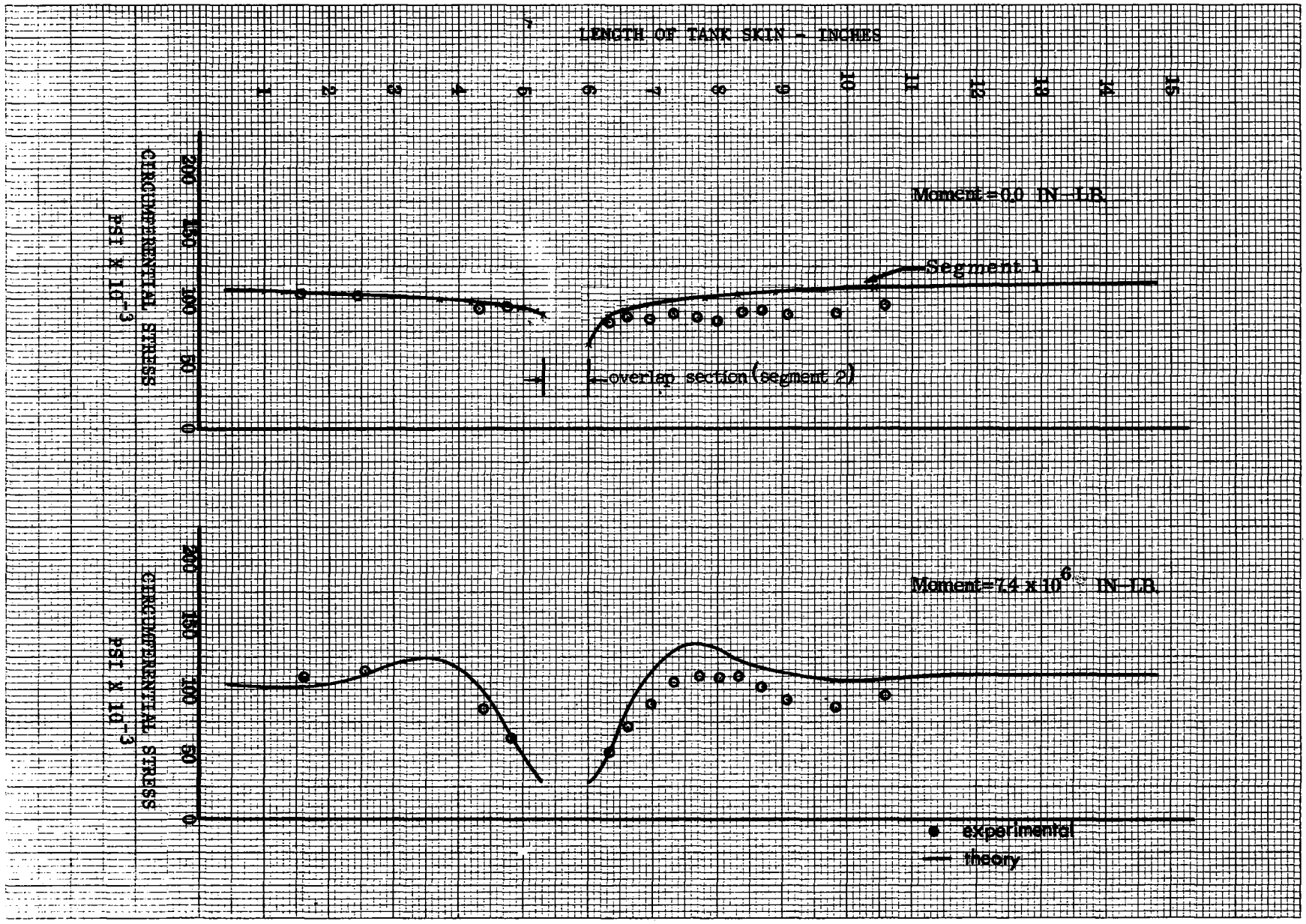


Figure 1.28 Circumferential Stress Versus S for $\theta = 0$

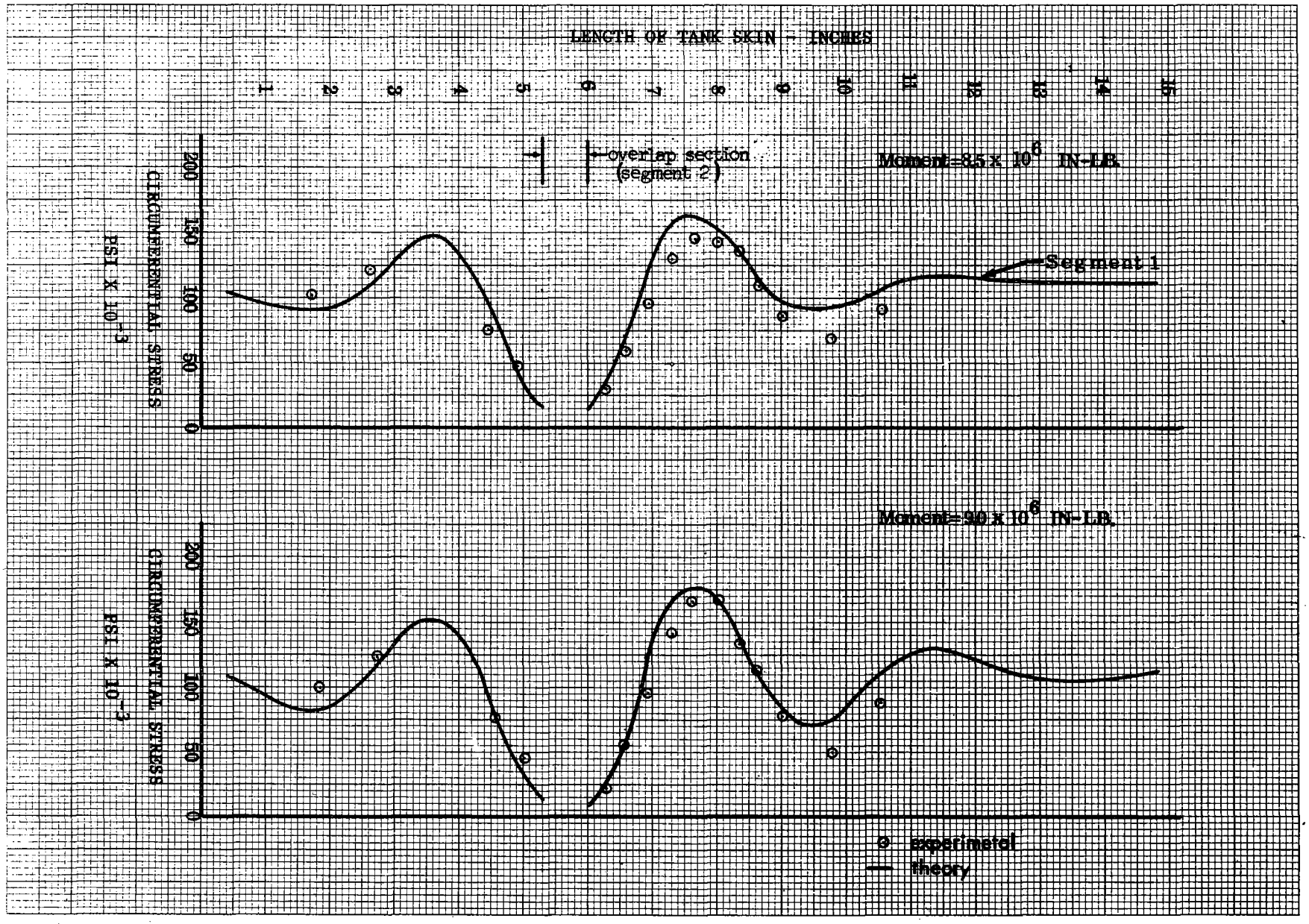


Figure 1.29 Circumferential Stress Versus S for $\theta = 0$

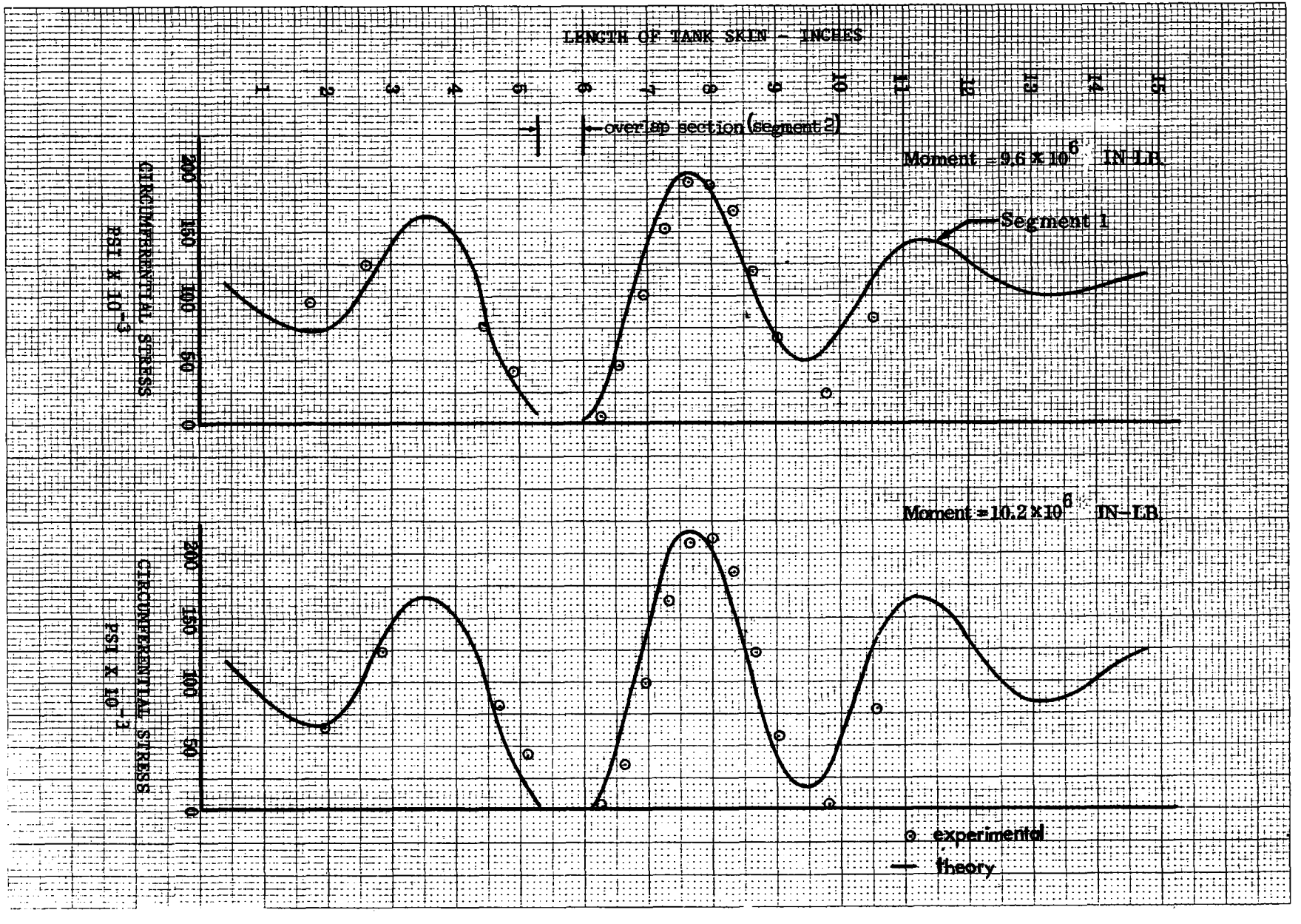


Figure 1.30 Circumferential Stress Versus S for $\theta = 0$

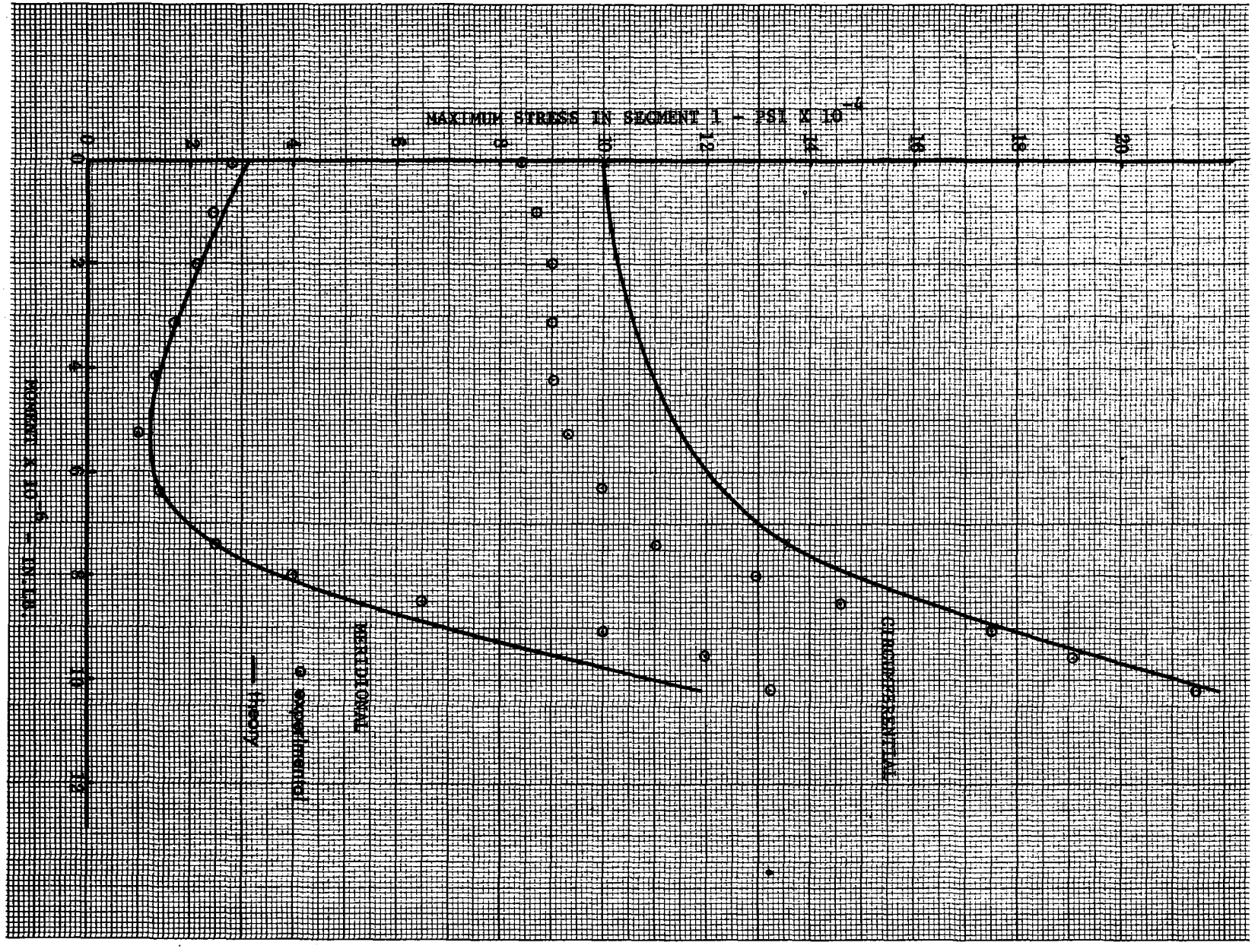


Figure 1.31 Maximum Stress in Segment 1 Versus Moment

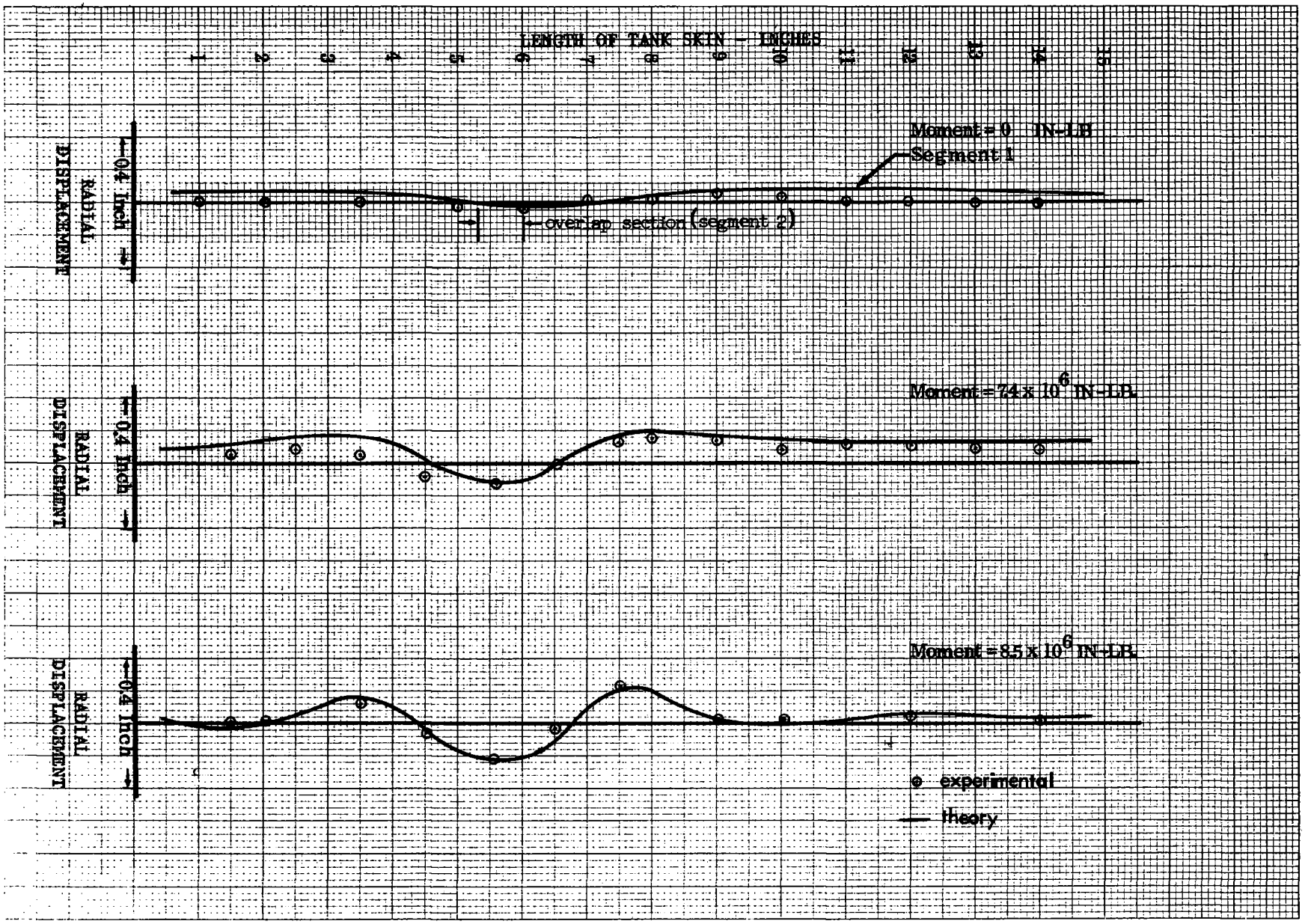


Figure 1.32 Radial Displacement Versus S for $\theta = 0$

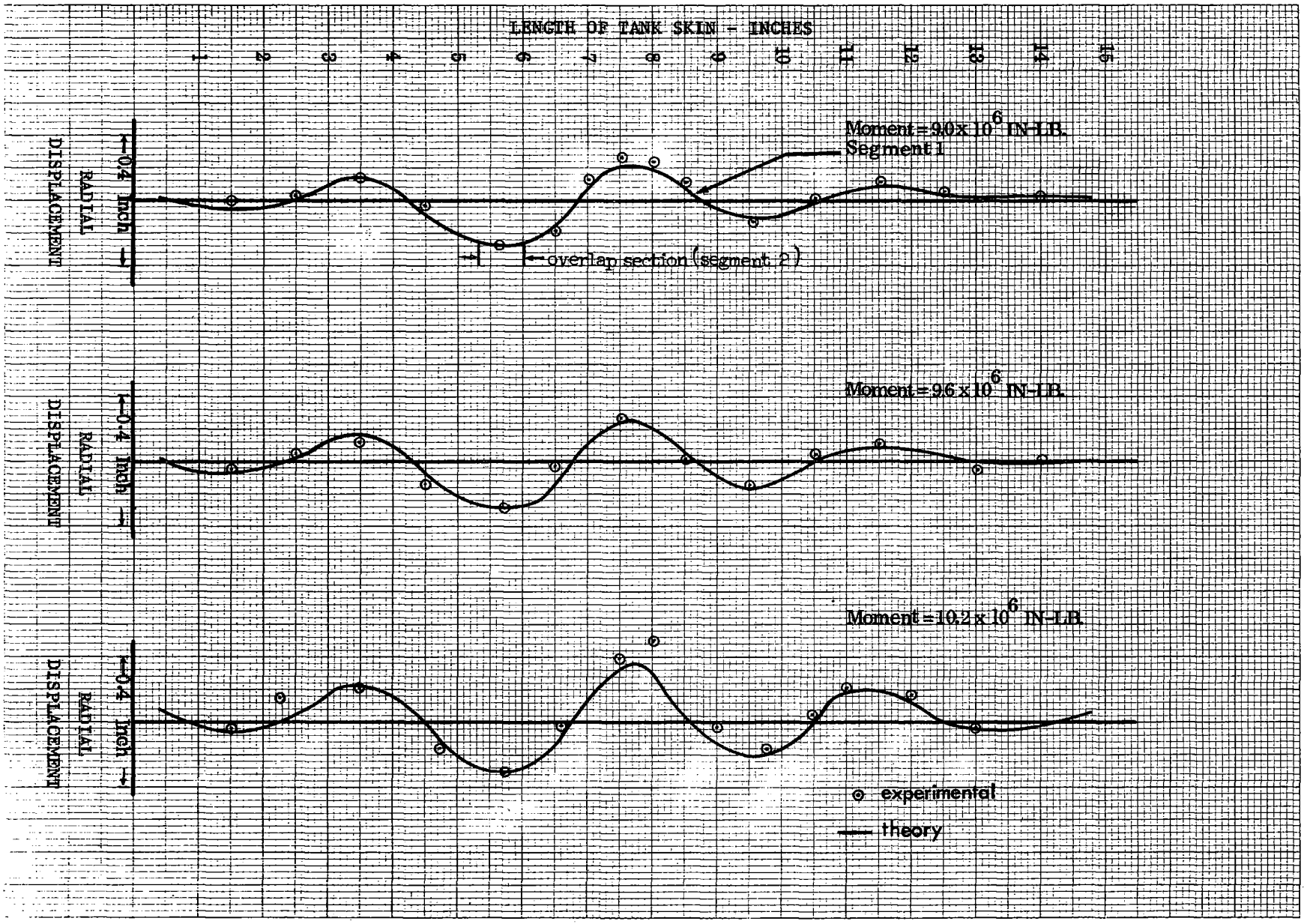


Figure 1.33 Radial Displacement Versus S for $\theta = 0$

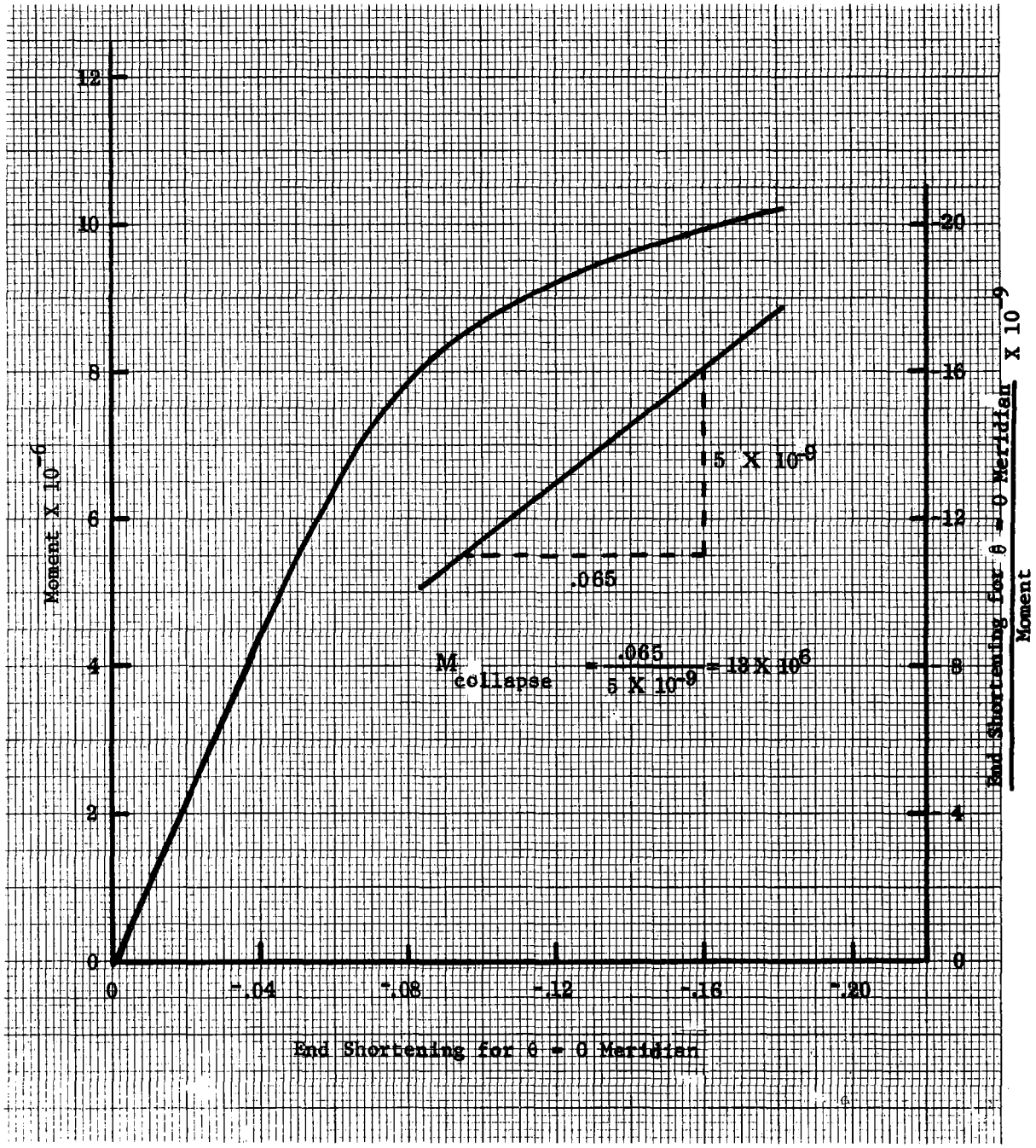


Figure 1.34 Moment Versus End Shortening

1.5 Conclusions and Recommendations

The conclusions obtained in the present investigation may be summarized as follows:

1. The method of solution presented in this report has been shown to yield good analytical solutions to geometrically complicated axisymmetric shells subject to nonsymmetric loading.
2. The solution of the Atlas post-wrinkling problem indicates that pressure stabilized structures can indeed be loaded well above the initial wrinkling load. However, the analysis did show that at bending moments approximately 50% greater than the initial wrinkling load, the stresses around the circumferential splice joints do become large.
3. The analytical results predicted that if the material remained elastic, the collapse moment would be approximately 1.93 times the moment at which wrinkling first occurs.

It is recommended that future work in this area should include the following:

1. To predict the ultimate load carrying capacity of the Atlas missile, the present analysis should be extended to include material property nonlinearity and plasticity effects.
2. The present analysis may easily be extended to include shells of arbitrary geometry. It is therefore recommended that the computer program be modified to include other geometrics.
3. One comment, concerning computation time, must be given to the potential user of this computer program. The program was written to operate on the 7094 computer. Although every effort was made to optimize the running time, the complexity of the analysis made it necessary to use many tapes. The sample problem presented in this report involved a total of 7,672 fundamental variables, and required a total of 2.5 hours of 7094 time to obtain the complete solution history. This time can be greatly reduced by using a third generation computer and faster secondary storage devices.

Appendix A

The coefficients of matrix [A], equations (16) are

$$A_{11} = -\frac{M^2(1-\mu^2)}{r^2}\left[D + K\frac{\sin^2\phi}{r^2}\right]$$

$$A_{12} = -MD(1-\mu^2)\frac{\cos\phi}{r^2}$$

$$A_{13} = -M(1-\mu^2)\frac{\sin\phi}{r^2}\left[D + \frac{M^2K}{r^2}\right]$$

$$A_{14} = -MK(1-\mu^2)\frac{\sin\phi\cos\phi}{r^3}$$

$$A_{15} = \frac{2\cos\phi}{r}$$

$$A_{16} = -\mu\frac{M}{r}$$

$$A_{18} = -\mu M\frac{\sin\phi}{r^2}$$

$$A_{21} = -MD(1-\mu^2)\frac{\cos\phi}{r^2}$$

$$A_{22} = -\frac{1}{r^2}\left[D(1-\mu^2)\cos^2\phi + 2M^2K(1-\mu)\frac{\sin^2\phi}{Lr^2}\right]$$

$$A_{23} = -\frac{\sin\phi\cos\phi}{r^2}\left[D(1-\mu^2) - 2M^2K\frac{(1-\mu)}{Lr^2}\right]$$

$$A_{24} = 2M^2K(1-\mu)\frac{\sin\phi}{r^3L}$$

$$A_{25} = \frac{M}{r}\left[1 - \frac{3K\sin^2\phi}{DLr^2}\right]$$

$$A_{26} = (1-\mu)\frac{\cos\phi}{r}$$

$$A_{31} = -\frac{M(1-\mu^2)}{r^2}\left[D + K\frac{\sin^2\phi}{r^2}\right]$$

$$A_{32} = -\frac{\sin\phi\cos\phi}{r^2}\left[D(1-\mu^2) - 2M^2K\frac{(1-\mu)}{Lr^2}\right]$$

$$A_{33} = -\frac{1}{r^2}\left[D(1-\mu^2)\sin^2\phi + 2M^2K\frac{(1-\mu)}{Lr^2}\cos^2\phi + \frac{M^4K(1-\mu^2)}{r^2}\right]$$

$$A_{34} = -\frac{M^2K\cos\phi}{r^3}\left[\frac{2(1-\mu)}{L} + (1-\mu^2)\right]$$

$$A_{35} = \frac{3MK}{DLr^3}\sin\phi\cos\phi$$

$$A_{36} = -\mu\frac{\sin\phi}{r}$$

$$A_{37} = \frac{\cos\phi}{r}$$

$$A_{38} = -\frac{M^2\mu}{r^2}$$

$$A_{41} = -MK(1-\mu^2)\frac{\sin\phi\cos\phi}{r^3}$$

$$A_{42} = \frac{2M^2K(1-\mu)}{Lr^3}\sin\phi$$

$$A_{43} = -\frac{M^2K\cos\phi}{r^3}\left[(1-\mu^2) + \frac{2(1-\mu)}{L}\right]$$

$$A_{44} = -\frac{K}{r^2}\left[(1-\mu^2)\cos^2\phi + \frac{2M^2}{L}(1-\mu)\right]$$

$$A_{45} = \frac{3MK\sin\phi}{LDr^2}$$

$$A_{47} = -1.0$$

$$A_{48} = \frac{\cos\phi}{r}(1-\mu)$$

$$A_{51} = -\frac{\cos\phi}{r}$$

$$A_{52} = -\frac{M}{Lr}\left[1 - \frac{3K}{4Dr^2}\sin^2\phi\right]$$

$$A_{53} = -\frac{3MK}{LDr^3}\sin\phi\cos\phi$$

$$A_{54} = -\frac{3MK}{LDr^2}\sin\phi$$

$$A_{55} = -\frac{2}{DL(1-\mu)}$$

$$A_{61} = \frac{\mu M}{r}$$

$$A_{62} = \frac{\mu\cos\phi}{r}$$

$$A_{63} = \frac{\mu\sin\phi}{r}$$

$$A_{66} = -1/D$$

$$A_{74} = 1.0$$

$$A_{81} = M\mu\frac{\sin\phi}{r^2}$$

$$A_{83} = \frac{M^2\mu}{r^2}$$

$$A_{84} = \frac{\mu\cos\phi}{r}$$

$$A_{88} = -1/K$$

All other "A" coefficients are zero.

Appendix B

The nonlinear terms in equations (17), may be obtained by expanding the product of two Fourier series into a third Fourier series. In general, there are three types of series expansions as follows:

I. Given:

$$A = \sum_{k=o}^{\infty} A_k \cos k\theta \quad , \qquad B = \sum_{\ell=o}^{\infty} B_k \sin k\theta$$

Determine:

$$A \cdot B = \sum_{k=o}^{\infty} \sum_{\ell=o}^{\infty} A_k B_\ell \cos k\theta \cos \ell\theta$$

$$= \sum_{m=o}^{\infty} \sum_{\ell=o}^{\infty} A_k B_\ell [\cos(k - \ell)\theta + \cos(k + \ell)\theta]$$

$$= A_o B_o + \frac{1}{2} \sum_{j=1}^{\infty} \frac{1}{2} A_j B_j + \sum_{M=1}^{\infty} \left\{ A_o B_M + A_M B_o + \frac{1}{2} \sum_{j=1}^{\infty} \left[A_j B_{M+j} + A_{M+j} B_j \right] \right.$$

$$\left. + \frac{1}{4} \sum_{j=1}^{M-1} \left[A_j B_{M-j} + A_{M-j} B_j \right] \right\} \cos M\theta \qquad \text{(B1)}$$

II. Given:

$$A = \sum_{k=1}^{\infty} A_k \sin k\theta \quad , \qquad B = \sum_{\ell=1}^{\infty} B_\ell \sin \ell\theta$$

Find:

$$A \cdot B = \sum_{k=1}^{\infty} \sum_{\ell=1}^{\infty} A_k B_\ell \sin k\theta \sin \ell\theta$$

$$= \frac{1}{2} \sum_{j=1}^{\infty} A_j B_j + \left\{ \sum_{M=1}^{\infty} \frac{1}{2} \sum_{j=1}^{\infty} \left[A_j B_{M+j} + A_{M+j} B_j \right] \right.$$

$$\left. - \frac{1}{4} \sum_{j=1}^{M-1} \left[A_j B_{M-j} + A_{M-j} B_j \right] \right\} \cos M\theta \qquad \text{(B2)}$$

III. Given:

$$A = \sum_{k=o}^{\infty} A_k \cos k\theta \quad , \qquad B = \sum_{\ell=1}^{\infty} B_\ell \sin \ell\theta$$

Find:

$$A \cdot B = \sum_{k=o}^{\infty} \sum_{\ell=1}^{\infty} A_k B_\ell \cos k\theta \sin \ell\theta$$

$$= \sum_{M=1}^{\infty} \left\{ A_o B_M + \frac{1}{2} \sum_{j=1}^{\infty} \left[A_j B_{M+j} - A_{M+j} B_j \right] \right.$$

$$\left. + \frac{1}{4} \sum_{j=1}^{M-1} \left[A_j B_{M-j} + A_{M-j} B_j \right] \right\} \sin M\theta \qquad \text{(B3)}$$

The terms involving products of series are now determined, for each harmonic M, by using equations (B1), (B2) and (B3).

$$\lambda_M^{(1)} = (N_{\phi\theta}\omega_\theta + N_\theta \omega_\theta)_M$$

$$= \zeta_M \left\{ N_{\phi\theta_M} \omega_{\theta_0} + N_{\theta_0} \omega_{\phi_M} \right.$$

$$+ \frac{1}{2} \sum_{j=1}^{\infty} \left[\omega_{\theta_j} N_{\phi\theta_{(M+j)}} + N_{\theta_j} \omega_{\phi_{(M+j)}} \right.$$

$$\left. - (\omega_{\theta_{(M+j)}} N_{\phi\theta_j} + N_{\theta_{(M+j)}} \omega_{\phi_j}) \right]$$

$$+ \frac{1}{4} \sum_{j=1}^{M-1} \left[\omega_{\theta_j} N_{\phi\theta_{(M-j)}} + N_{\theta_j} \omega_{\phi_{(M-j)}} \right.$$

$$\left. \left. + (\omega_{\theta_{(M-j)}} N_{\phi\theta_j} + N_{\theta_{(M-j)}} \omega_{\phi_j}) \right] \right\} \qquad \text{(B4)}$$

$$\lambda_M^{(2)} = [(N_\phi + N_\theta)\omega]_M$$

$$= \zeta_M \left\{ (N_{\phi_0} + N_{\theta_0})\ \omega_M \right.$$

$$+ \frac{1}{2} \sum_{j=1}^{\infty} \left[(N_{\phi_j} + N_{\theta_j})\omega_{(M+j)} - (N_{\phi_{(M+j)}} + N_{\theta_{(M+j)}})\ \omega_j \right]$$

$$\left. + \frac{1}{4} \sum_{j=1}^{M-1} \left[(N_{\phi_j} + N_{\theta_j})\ \omega_{(M-j)} + (N_{\phi_{(M-j)}} + N_{\theta_{(M-j)}})\ \omega_j \right] \right\} \tag{B5}$$

$$\lambda_M^{(3)} = (\omega_\phi^2 + \omega^2)_M$$

$$= (1 - \zeta_M) \left[\frac{1}{2} \sum_{j=1}^{\infty} (\omega_{\phi_j}^2 + \omega_j^2) \right]$$

$$+ \zeta_M \left\{ \sum_{j=1}^{\infty} \left[\omega_{\phi_j} \omega_{\phi_{(M+j)}} + \omega_j \omega_{(M+j)} \right] \right.$$

$$\left. - \frac{1}{2} \sum_{j=1}^{M-1} \left[\omega_{\phi_j} \omega_{\phi_{(M-j)}} + \omega_j\ \omega_{(M-j)} \right] \right\} \tag{B6}$$

$$\lambda_M^{(4)} = (\omega_\theta\ \omega_\phi)_M$$

$$= \zeta_M \left\{ \omega_{\theta_0}\ \omega_{\phi_M} + \frac{1}{2} \sum_{j=1}^{\infty} \left[\omega_{\theta_j}\ \omega_{\phi_{(M+j)}} - \omega_{\theta_{(M+j)}}\ \omega_{\phi_j} \right] \right.$$

$$\left. + \frac{1}{4} \sum_{j=1}^{M-1} \left[\omega_{\theta_j}\ \omega_{\phi_{(M-j)}} + \omega_{\theta_{(M-j)}} \omega_{\phi_j} \right] \right\} \tag{B7}$$

$$\lambda_M^{(5)} = (N_\phi \, \omega_\theta + N_{\phi\theta} \, \omega_\phi)_M$$

$$= (1 - \zeta_M) \left[N_{\phi_0} \, \omega_{\theta_0} + \frac{1}{2} \sum_{j=1}^{\infty} (N_{\phi_j} \, \omega_{\theta_j} + N_{\phi\theta_j} \, \omega_{\phi_j}) \right]$$

$$+ \zeta_M \left\{ N_{\phi_0} \, \omega_{\theta_M} + N_{\phi_M} \, \omega_{\theta_0} \right.$$

$$+ \frac{1}{2} \sum_{j=1}^{\infty} \left[N_{\phi_j} \, \omega_{\theta_{(M+j)}} + N_{\phi\theta_j} \, \omega_{\phi_{(M+j)}} \right.$$

$$\left. + N_{\phi_{(M+j)}} \, \omega_{\theta_j} + N_{\phi\theta_{(M+j)}} \, \omega_{\phi_j} \right]$$

$$+ \frac{1}{4} \sum_{j=1}^{M-1} \left[N_{\phi_j} \, \omega_{\theta_{(M-j)}} - N_{\phi\theta_j} \, \omega_{\phi_{(M-j)}} \right.$$

$$\left. \left. + N_{\phi_{(M-j)}} \, \omega_{\theta_j} - N_{\phi\theta_{(M-j)}} \, \omega_{\phi_j} \right] \right\} \qquad \text{(B8)}$$

$$\lambda_M^{(6)} = (\omega^2 + \omega^2)_M$$

$$= (1 - \zeta_M) \left[\omega_{\theta_0}^2 + \frac{1}{2} \sum_{j=1}^{\infty} (\omega_{\theta_j}^2 + \omega_j^2) \right]$$

$$+ \zeta_M \left\{ 2\omega_{\theta_0} \, \omega_{\theta_M} + \sum_{\ell=1}^{\infty} \left[\omega_{\theta_j} \, \omega_{\theta_{(M+j)}} + \omega_j \, \omega_{(M+j)} \right] \right.$$

$$\left. + \frac{1}{2} \sum_{j=1}^{M-1} \left[\omega_{\theta_j} \, \omega_{\theta_{(M-j)}} + \omega_j \, \omega_{(M-j)} \right] \right\} \qquad \text{(B9)}$$

$$\lambda_M^{(7)} = (\overline{Z}\ \omega_\theta)_M$$

$$= (1 - \zeta_M)\left[\overline{Z}_0\ \omega_{\theta_0} + \frac{1}{2}\sum_{j=1}^{\infty}\overline{Z}_j\ \omega_{\theta_j}\right]$$

$$+ \zeta_M\left\{\overline{Z}_0\ \omega_{\theta_M} + \overline{Z}_M\ \omega_{\theta_0} + \frac{1}{2}\sum_{j=1}^{\infty}\left[\overline{Z}_j\omega_{\theta_{(M+j)}} + \overline{Z}_{(M+j)}\ \omega_{\theta_j}\right]\right.$$

$$\left. + \frac{1}{4}\sum_{j=1}^{M-1}\left[\overline{Z}_j\ \omega_{\theta_{(M-j)}} + \overline{Z}_{(M-j)}\ \omega_{\theta_j}\right]\right\} \qquad \text{(B10)}$$

$$\lambda_M^{(8)} = (\overline{Z}\ \omega_\phi)_M$$

$$= \zeta_M\left\{\overline{Z}_0\ \omega_{\phi_M} + \frac{1}{2}\sum_{j=1}^{\infty}\left[\overline{Z}_j\ \omega_{\phi_{(M+j)}} - \overline{Z}_{(M+j)}\ \omega_{\phi_j}\right]\right.$$

$$\left. + \frac{1}{4}\sum_{j=1}^{M-1}\left[\overline{Z}_j\ \omega_{\phi_{(M-j)}} + \overline{Z}_{(M-j)}\ \omega_{\phi_j}\right]\right\} \qquad \text{(B11)}$$

$$\lambda_M^{(9)} = [\overline{Z}(\overline{\varepsilon}_\phi + \overline{\varepsilon}_\theta)]_M + [\overline{Z}(\overline{\varepsilon})]_M$$

$$= (1 - \zeta_M)\left[\overline{Z}_0\overline{\varepsilon}_0 + \frac{1}{2}\sum_{j=1}^{\infty}\overline{Z}_j\overline{\varepsilon}_j\right]$$

$$+ \zeta_M\left\{\overline{Z}_0\overline{\varepsilon}_M + \overline{Z}_M\overline{\varepsilon}_0 + \frac{1}{2}\sum_{j=1}^{\infty}\left[\overline{Z}_j\overline{\varepsilon}_{(M+j)} + \overline{Z}_{(M+j)}\overline{\varepsilon}_j\right]\right.$$

$$\left. + \frac{1}{4}\sum_{j=1}^{M-1}\left[\overline{Z}_j\overline{\varepsilon}_{(M-j)} + \overline{Z}_{(M-j)}\overline{\varepsilon}_j\right]\right\} \qquad \text{(B12)}$$

where $\zeta_M = 0$ for $M = 0$

$\zeta_M = 1$ for $M \geq 1$

Appendix C

The coefficients of the matrix [A*] are given in this appendix. For simplicity, in the derivation of these coefficients the nonlinear term $\lambda_M^{(2)}$ was not included, and the force $\overline{N}_{\phi\theta}$ was used in place of $N_{\phi\theta}$. The term $\lambda_M^{(2)}$ is usually negligible and not included in some nonlinear shell theories and $N_{\phi\theta}$ is approximately equal to $\overline{N}_{\phi\theta}$ for thin shell problems. This greatly simplified the expressions for the "A*" coefficients, and is consistent with the iteration method. In this method, the matrix [A*] is not recalculated for each iteration, but only when convergence becomes poor, and need not be exact. It should be noted that the simplifications given above were <u>not</u> made in deriving the right side of equations (22), and hence the converged solution is still based on the original equations.

$$A_{11}^* = A_{11} - \frac{\sin^2\phi}{r^2}\left[N_{\theta_0} + D(1-\mu^2)\Omega_{\phi_0} - \frac{1}{2}N_{\theta_{2M}}\right]$$

$$- MD(1-\mu^2)\frac{\sin\phi}{r^2}\omega_{\phi_{2M}} + \overline{Z}\frac{\sin\phi}{r}$$

$$A_{12}^* = A_{12} - D(1-\mu^2)\frac{\sin\phi\cos\phi}{2r^2}\omega_{\phi_{2M}}$$

$$A_{13}^* = A_{13} - \frac{M\sin\phi}{r^2}\left[N_{\theta_0} + D(1-\mu^2)\Omega_{\phi_0} - \frac{1}{2}N_{\theta_{2M}}\right]$$

$$- \frac{D(1-\mu^2)}{2r^2}\left[M^2 + \sin^2\phi\,\omega_{\phi_{2M}}\right] + \frac{M\overline{Z}}{r}$$

$$A_{14}^* = A_{14} - \frac{\sin\phi}{2r}\overline{N}_{\phi\theta_{2M}}$$

$$A_{15}^* = A_{15} - \frac{\sin\phi}{r}\left(\omega_{\theta_0} - \frac{1}{2}\omega_{\theta_{2M}}\right)$$

$$A_{16}^* = A_{16} - \mu\frac{\sin\phi}{2r}\omega_{\phi_{2M}}$$

$$A^*_{21} = A_{21} + \frac{3MK(1-\mu)\sin^3\phi}{2Lr^4}\left(\omega_{\theta_0} - \frac{1}{2}\omega_{\theta_{2M}}\right) - D(1-\mu^2)\frac{\sin\phi\cos\phi}{2r^2}\omega_{\phi_{2M}}$$

$$A^*_{23} = A_{23} + \frac{3M^2K(1-\mu)\sin^2\phi}{2Lr^4}\left(\omega_{\theta} - \frac{1}{2}\omega_{\theta_{2M}}\right) - MD(1-\mu^2)\frac{\cos\phi}{2r^2}\omega_{\phi_{2M}}$$

$$A^*_{24} = A_{24} + \frac{3MK(1-\mu)\sin^2\phi}{4Lr^3}\omega_{\phi_{2M}} + \overline{Z}$$

$$A^*_{31} = A_{31} - \frac{M}{r^2}\sin\phi\left[N_{\theta_0} + D(1-\mu^2)\Omega_{\phi_0} - \frac{1}{2}N_{\theta_{2M}} + \frac{3K(1-\mu)}{2Lr^2}\sin\phi\cos\phi\left(\omega_{\theta_0} - \frac{1}{2}\omega_{\theta_{2M}}\right)\right] - \frac{D(1-\mu^2)}{2r^2}(M^2 + \sin^2\phi)\,\omega_{\phi_{2M}}$$

$$A^*_{32} = A_{32} - MD(1-\mu^2)\frac{\cos\phi}{2r^2}\omega_{\phi_{2M}}$$

$$A^*_{33} = A_{33} - \frac{M^2}{r^2}\left[N_{\theta_0} + D(1-\mu^2)\Omega_{\phi_0} - \frac{1}{2}N_{\theta_{2M}} + \frac{3K(1-\mu)}{2Lr^2}\sin\phi\cos\phi\left(\omega_{\theta_0} - \frac{1}{2}\omega_{\theta_{2M}}\right)\right] - \frac{D(1-\mu^2)}{2r^2}(M^2 + \sin^2\phi)\,\omega_{\phi_{2M}}$$

$$A^*_{34} = A_{34} - \frac{M}{2r}\overline{N}_{\phi\theta_{2M}} - \frac{3MK(1-\mu)}{4Lr^3}\sin\phi\cos\phi\,\omega_{\phi_{2M}}$$

$$A^*_{35} = A_{35} - \frac{M}{r}\left(\omega_{\theta_0} - \frac{1}{2}\omega_{\theta_{2M}}\right)$$

$$A^*_{36} = A_{36} - \frac{\mu M}{2r}\omega_{\phi_{2M}}$$

$$A^*_{41} = A_{41} - \frac{3MK(1-\mu)}{2Lr^3}\sin^2\phi\left(\omega_{\theta_0} - \frac{1}{2}\omega_{\theta_{2M}}\right) - \frac{\sin\phi}{2r}\overline{N}_{\phi\theta_{2M}}$$

$$A^*_{43} = A_{43} - \frac{3M^2K(1 - \mu)}{2Lr^3} \sin \phi(\omega_{\theta_0} - \frac{1}{2} \omega_{\theta_{2M}}) - \frac{M}{2r} \overline{N}_{\phi\theta_{2M}}$$

$$A^*_{44} = A_{44} - (N_{\phi_0} + \frac{1}{2} N_{\phi_{2M}}) - \frac{3MK(1 - \mu)\sin \phi}{4Lr^2} \omega_{\phi_{2M}}$$

$$A^*_{45} = A_{45} - \frac{1}{2} \omega_{\phi_{2M}}$$

$$A^*_{46} = A_{46} - (\omega_{\theta_0} - \frac{1}{2} \omega_{\theta_{2M}})$$

$$A^*_{51} = A_{51} + \frac{\sin \phi}{rL}(\omega_{\theta_0} - \frac{1}{2} \omega_{\theta_{2M}})$$

$$A^*_{53} = A_{53} + \frac{M}{rL} (\omega_{\theta_0} - \frac{1}{2} \omega_{\theta_{2M}})$$

$$A^*_{54} = A_{54} + \frac{1}{2L} \omega_{\phi_{2M}}$$

$$A^*_{64} = A_{64} + \omega_{\theta_0} + \frac{\omega_{\theta_{2M}}}{2}$$

where

$$\Omega_{\phi_0} = \frac{1}{2} \sum_{j=1}^{\infty} \omega^2_{\phi_j}$$

and all other "A*'s" equal the "A" coefficients given in Appendix A.

II. COMPUTER PROGRAM

2.1 Introduction

The analysis and numerical method presented in Section I of this report was programmed in Fortran IV for use on the IBM 7094 digital computer. This program was primarily developed to obtain the elastic post-wrinkling behavior of highly pressurized conical shells of revolution subject to bending loads, but was written in a general form and may be used to solve many other nonlinear shell problems.

The solution is based on Sanders' nonlinear shell theory. All variables are expanded in a Fourier series in the circumferential direction. The governing nonlinear partial differential equations are thus converted to eight nonlinear ordinary first-order differential equations which are solved by use of a finite difference method. The nonlinear solution is obtained by using a modified Newton iteration technique.

To determine the solution to complicated shell problems, a methematical model of the actual shell must first be obtained. It is necessary to subdivide the shell into segments such that each segment does not contain discontinuities in geometry, material properties or loading. Each segment is numbered according to its physical order in the shell. Points which separate segments are called discontinuity points, and the first and last point of the shell are called boundary points.

The program input data consists of information pertaining to the overall problem, the individual segments, the surface loads on each segment, the discontinuity points and the boundary points.

In the first part of this section, a description of the input and output data, a sample problem, and the program operating procedure will be presented. This information should provide the user with the necessary background to effectively use this program. The latter part of this section contains the detailed description of the program, and the flow charts for the main monitors of the program. The Fortran listing of this program is given in Volume 2 of this report.

2.2 General Input Data Description

2.2.1 Shell Segments

The program obtains the nonlinear solution of shell problems by use of the finite difference method. Thus, the first step toward obtaining a solution for any shell problem is to determine a suitable mathematical model for the shell. Since the fundamental variables may be discontinuous at points where the geometry or material properties have abrupt changes, the shell must first be subdivided into segments. In general, discontinuities in material properties, geometry or surface loading will provide a natural criterion for the subdivision of the shell.

The geometry of each conical segment is input to the program by specifying the coordinates of the first and last point in the segment. A Cartesian coordinate system is used with variables R and Y. The convention is that the Y axis is always identical with the axis of revolution, while the R axis intersects the shell at any convenient point.

A typical shell configuration is shown in Figure 2.1. This shell consists of three segments. The points (a) and (b) indicate, respectively, the leading and trailing boundaries of the shell at which suitable boundary conditions must be imposed. The program allows sixteen possible boundary conditions. Their definitions are given in Table 2.1. The user must specify a physically compatible set of four conditions, for each Fourier harmonic under consideration, at each boundary of the shell.

Points (c) and (d) of Figure 2.1 indicate discontinuity points. In this configuration point (c) is a discontinuity because of the change in geometry between segment 1 and 2. At point (d) the unequal thickness between segments 2 and 3 requires that this point be a discontinuity point.

Since the finite difference method is used to solve the governing equations, each segment must be further subdivided into small intervals. The solution is obtained at the end points of each interval. In most shell problems the solution varies more rapidly near discontinuity and boundary points and thus it is best to use a finer mesh in these areas. To obtain the finite difference mesh for each segment, (i.e., the "S" mesh), the user must specify the

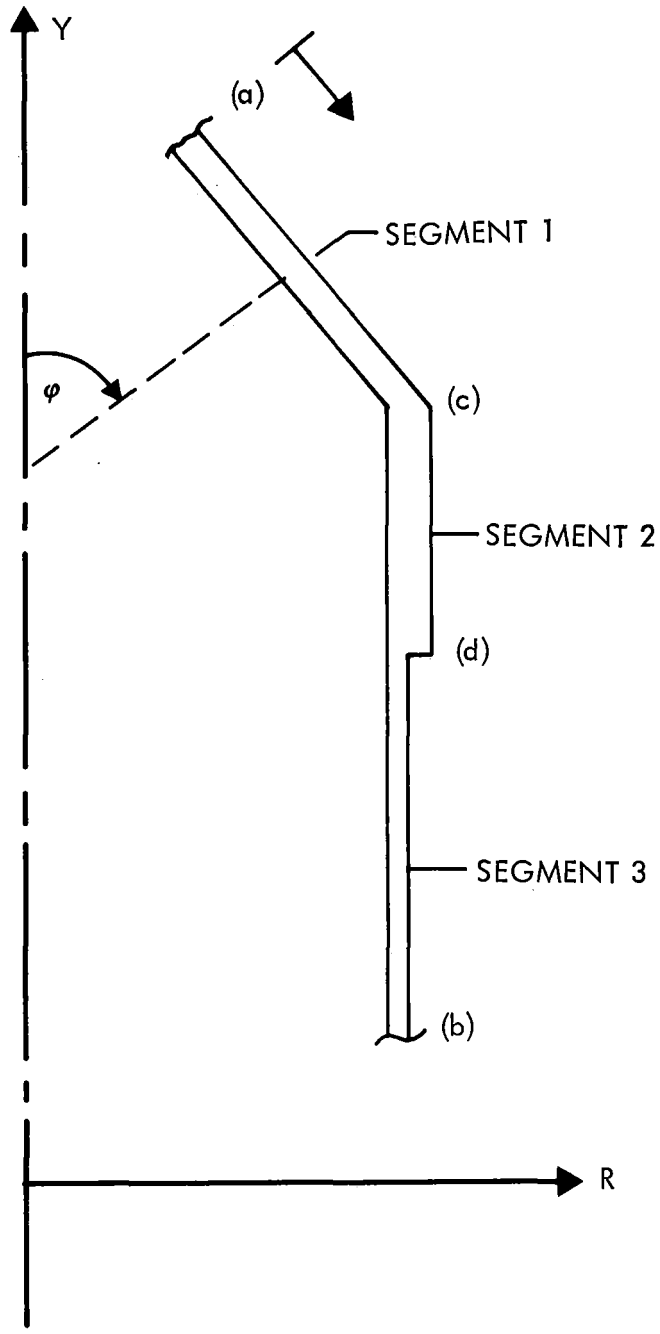


Figure 2.1 Typical Shell Configuration

total number of intervals in each segment (maximum = 73) and the number of unequally spaced intervals which he wishes to use near the end points of the segment. In addition, the size of the first and last interval must be given. The program will then automatically generate the "S" mesh for the segment by using an arithmetic progression, and will give the desired high point density near the ends of the segment.

The program also permits linear variations in the thickness and material properties between the end points of each segment. These quantities are input by specifying their values at the first and last point of the segment. The program will automatically calculate the magnitude of these quantities at all interior points.

It must be emphasized that care be exercised in obtaining the mathematical model for the actual shell. Some ambiguities may be observed in defining the geometry at discontinuities. The user is reminded that shell theory is only a two-dimensional theory and must be used in that context.

2.2.2 Elastic Supports and Line Loads

The program has the capability of solving problems involving branched shells, discrete rings and line loads. Branched shells and discrete rings are represented as elastic supports in the mathematical model of the actual structure. The program is presently restricted to handle only problems for which the elastic support stiffness matrix is linear. Section 1.3.3 gives the definitions and sign convention for the coefficients of the elastic support stiffness matrix. In general, the elastic support stiffness matrix will be different for each harmonic under consideration. These separate matrices are input in the elastic support input data.

2.2.3 Surface Loads

The program determines the solution of nonsymmetrically loaded shells of revolution by expanding the variables in a Fourier series in the circumferential direction. All loading data must therefore be represented by a Fourier series and each term of the series must be input to the program (maximum number of harmonics = 7).

Since the individual harmonic solutions are not uncoupled, it is possible to obtain solutions for harmonics which do not have any loading terms. The user must therefore decide which additional harmonics he wishes to consider and input zero loadings for these harmonics. The program determines the solution for each harmonic specified, and sums the solution for all harmonics at increments of the circumferential angle, θ.

The program obtains the nonlinear solution of shell problems by following the load-deformation history. The user must input the "starting" value of the loads, the value of the loading increments and the number of load levels (one plus the number of increments) for which a solution is to be obtained. The program will start with the first load level, iterate on the solution until the convergence criteria are met, print these results and proceed with the next load level.

After solutions for a specified number of load levels have been obtained, the program may be stopped so that the results may be studied, and restarted at the next load level. This capability also enables the user to obtain the load deflection history by making a number of runs using different load levels. Furthermore, if the program does not converge to a solution in the specified maximum number of iterations, the program may be restarted using an "update" restart option described in Section 2.3.5.

2.3 Input Cards Format

2.3.1 Introduction

This section describes the input data for the program. The order of the input data is pictorially described in Figures 2.2 through 2.6. The input data consists of the following four parts: case flags and options, leading and trailing boundary conditions, segment data, and restart data.

The most convenient keypunching form on which to enter data contains eighty columns. Each line is punched on one card in the format given for that line. Users should be familiar with "A", "E", "F" and "I" field specifications. The input data is contained in columns one through seventy. Columns seventy-one through eighty may be used for card sequencing or any method of card identification desired by the user. Any consistent system of units can be used for the input data.

2.3.2 Case Flags and Options

1. Comments. One card of comments concerning the case must be input.

   | Case Comments | (12A6)

2. Case Flags. The case flags specify basic information about this problem.

   FORMAT

   | I_1 | I_2 | I_3 | I_4 | (4I10)

   I_1 = The number of segments in the shell ($1 \leq I_1 \leq 7$)

   I_2 = The number of harmonics for this problem ($1 \leq I_2 \leq 7$)

   I_3 = The number of loading steps for this problem ($1 \leq I_3 \leq 10$)

   I_4 = The number of "special iterations" to be performed for the harmonic M = 0. If M = 0 is not in the harmonic list I_4 must be 0.

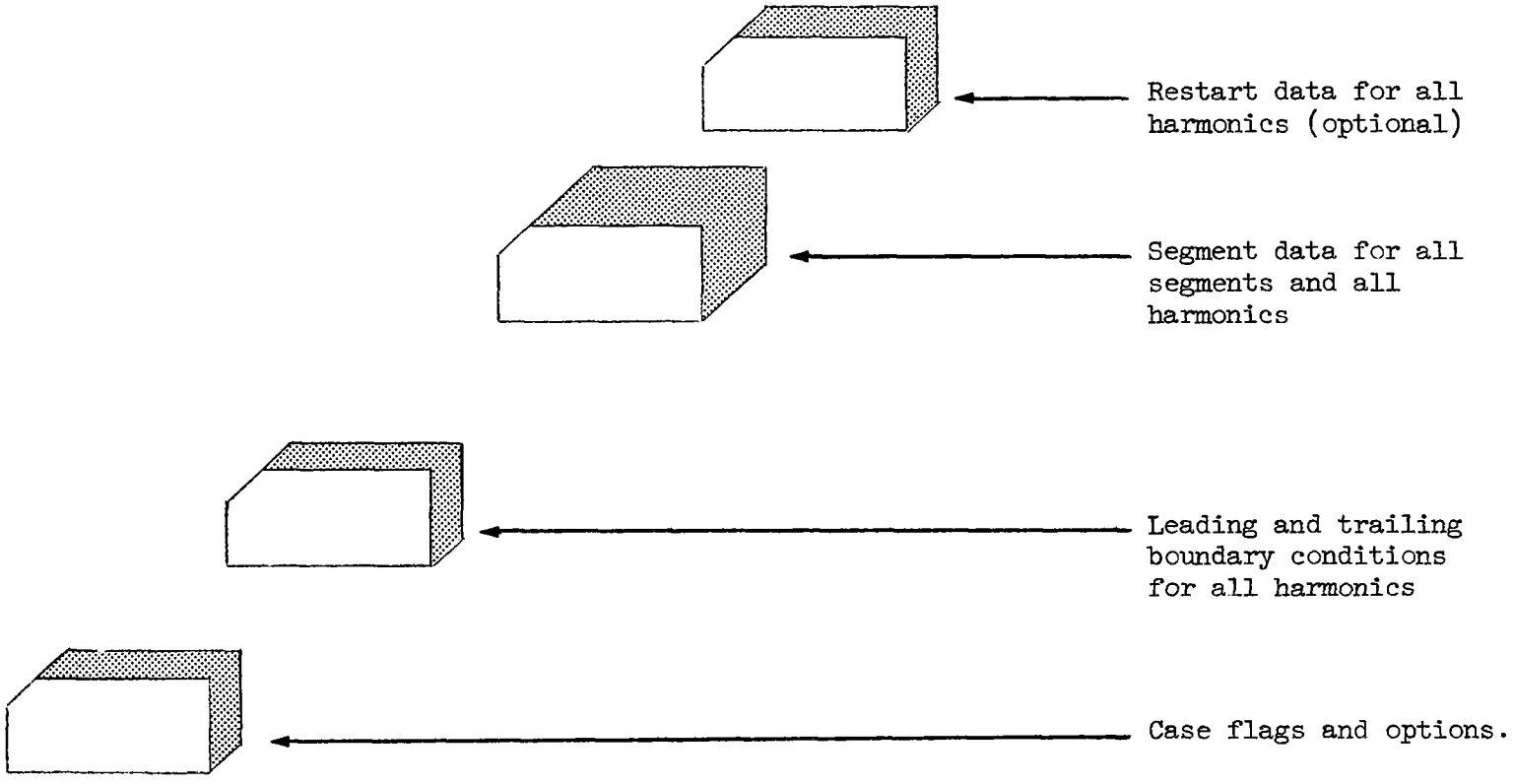


Figure 2.2 Order of Input Data

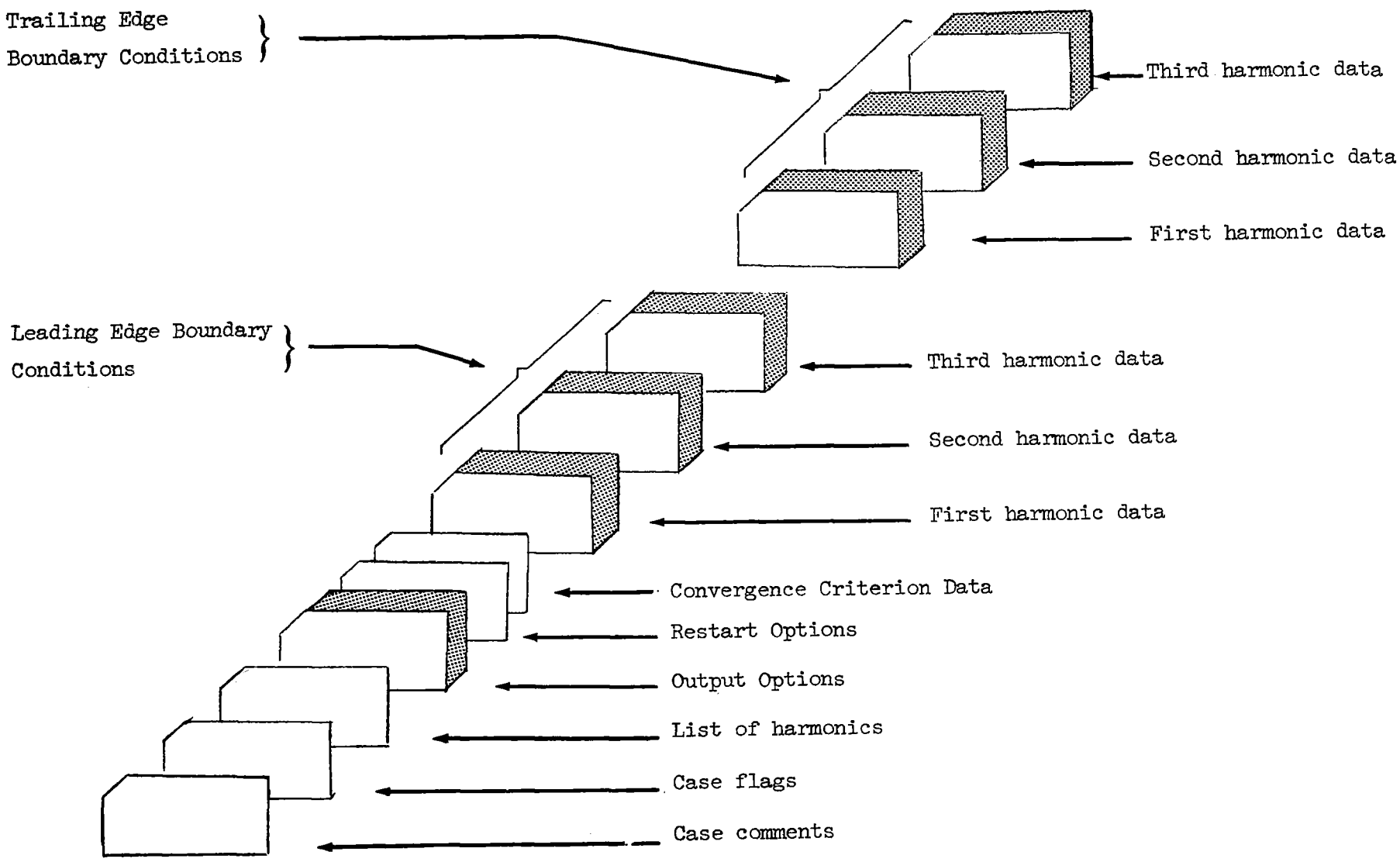


Figure 2.3 Order of Case Flags and Boundary Conditions

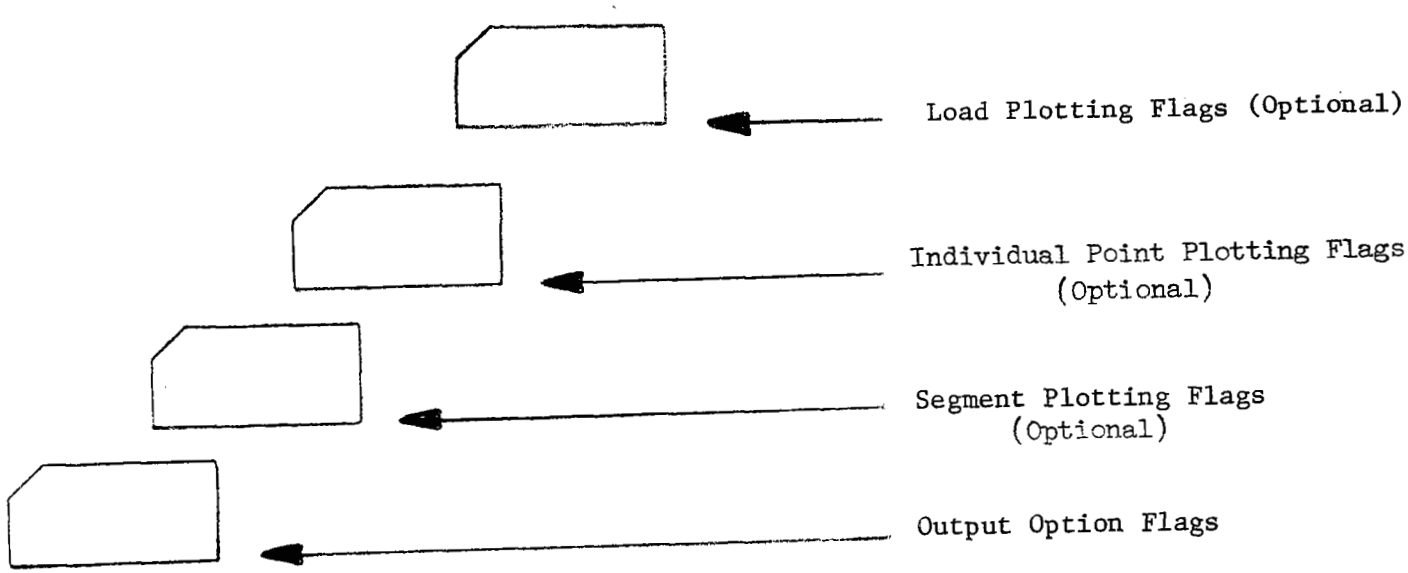


Figure 2.4 Output Options and Plotting Flags

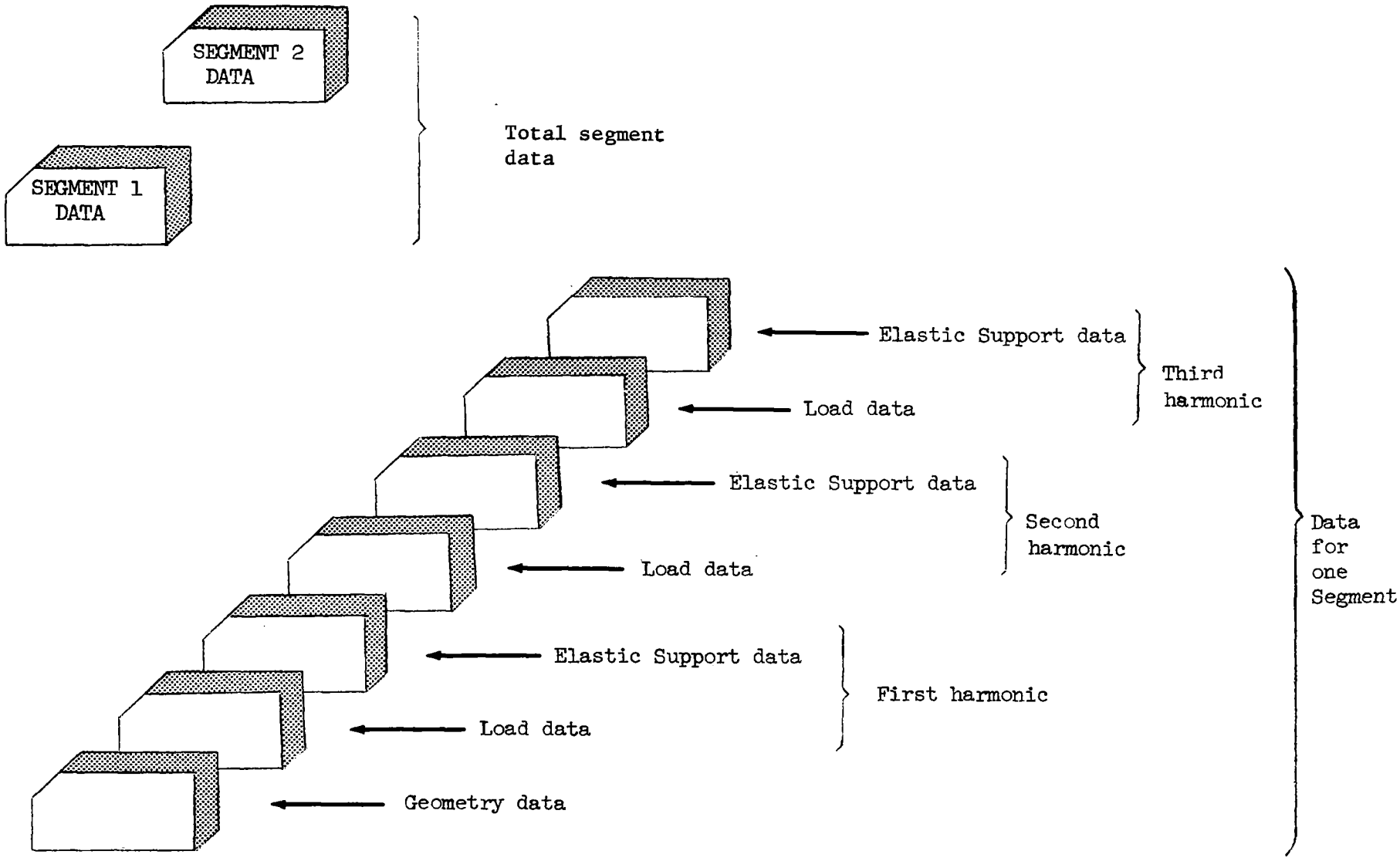


Figure 2.5 Order of Segment Data

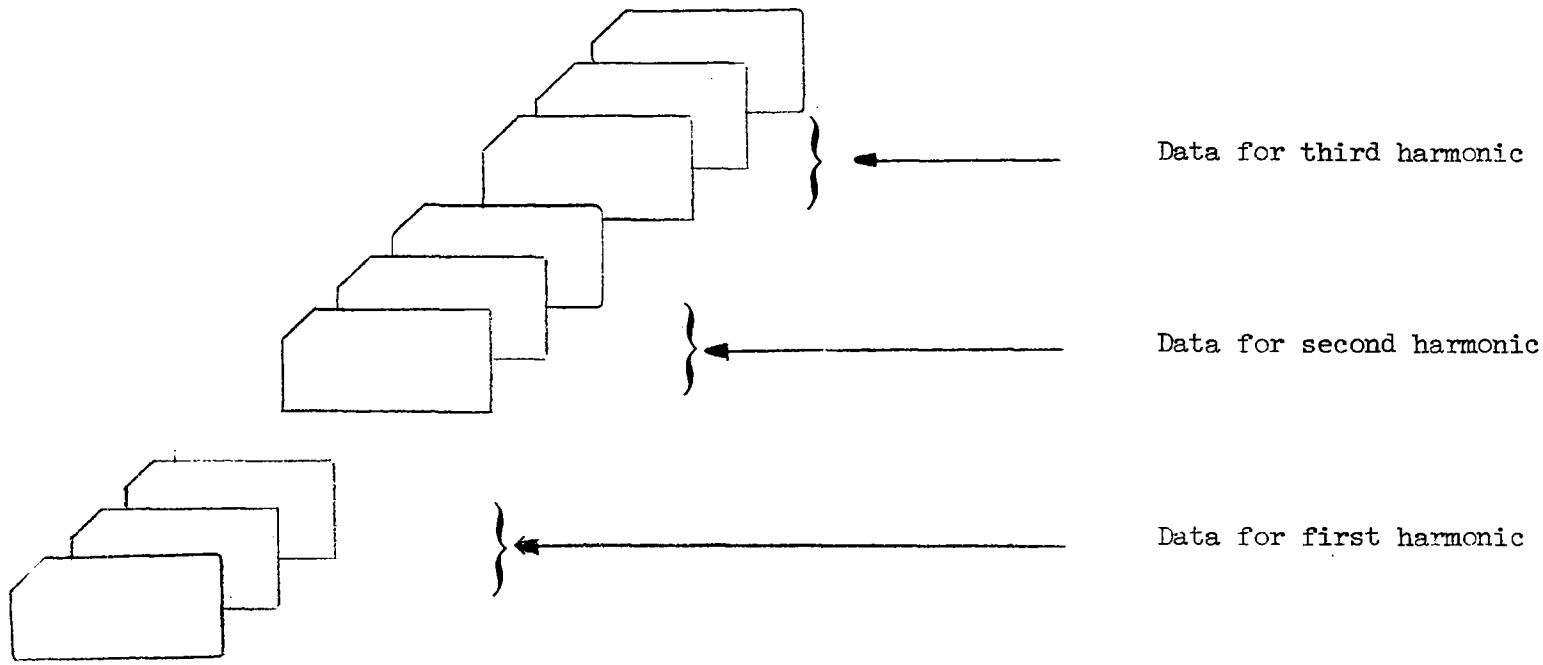


Figure 2.6 Order of Restart Data

Limitations

(a) $1 \leq I_1 \leq 7$
(b) $1 \leq I_2 \leq 7$
(c) $1 \leq I_3 \leq 10$
(d) $I_4 \geq 0$

3. Harmonic List. The harmonic list contains the values of those Fourier terms which the user wishes to consider. The order in which these harmonics are listed must be maintained throughout the remainder of the input data; for simplicity, they can be entered in increasing order. However, if one of the harmonics equals zero, it must be the first harmonic in the list.

FORMAT

J_1	J_2	J_3	J_4	J_5	J_6	J_7

(7I10)

J_I = the value of the "I^{th}" harmonic.

LIMITATIONS

$1 \leq I \leq 7$

4. Output Options. The output options specify what information is to be printed or plotted.

K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}	K_{13}	K_{14}

(14I5)

The first four options control the printing of information calculated prior to the solution of equations. The last nine options concern the printing or plotting of the solution at each load level.

K_1 Controls the printing of the geometry calculations. [S mesh, R and Y arrays, the angle ϕ, the sin (ϕ) and the cos (ϕ)]

= 0 Do not print the geometry calculations

= 1 Do print the geometry calculations

K_2 Controls the printing of the central differences for the first (n-1) points of each segment where "n" is the number of points in each segment.

= 0 Do not print.

= 1 Do print.

K_3 Controls the printing of the physical characteristics of each segment (Young's modulus, thickness, and Poisson's ratio) and the extensional and bending stiffness at each point.

= 0 Do not print.

= 1 Do print.

K_4 Controls the printing of the matrix of the governing equations and the initial right hand vector. Because of the large amount of output given by K_4, this option should be exercised only in program checkout.

= 0 Do not print.

= 1 Do print.

K_5 Used in initial checkout of program. Must be set equal to zero.

K_6 Controls the printing of the separate and/or combined harmonic results at each load level.

= 0 Do not print either the separate or the combined harmonic results.

= 1 Print only the separate harmonic results for each harmonic.

= 2 Print only the combined harmonic results.

= 3 Print both the separate and combined harmonic results.

K_7 Controls the printing of the displacements, rotations and forces.

= 0 Do not print the displacements, rotations or the forces.

= 1 Print only the displacements and rotations.

= 2 Print only the forces.

= 3 Print the displacements, rotations and the forces.

K_8 Specifies the number of points that will be printed in the separate or combined harmonic results.

= 0 or 1 Print every point.

= "number" Print every "number" point of each segment starting with the first point and finishing with the last point of each segment.

K_9 Specifies the size of the increment to the angle θ in the combined harmonic printing.

= 0, set $\Delta\theta$ = 20 degrees.

= m, calculate $\Delta\theta$

$\Delta\theta = 180/m$

In either case, begin with θ = 0 degrees and finish with θ = 180 degrees.

K_{10} Controls the printing at each load level.

= 0 or 1 Print each load level.

= "number" Print every "number" load level beginning with the first and finishing with the last.

K_{11} Specifies the number of segments for which segment plotting flags <u>must</u> be input.

= 0 No plotting. <u>Do not</u> input the segment plot flags.

= "number" There is plotting. Input the segment plotting flags for "number" segments. See segment plotting flags.

K_{12} Specifies the number of individual points at which the forces should be plotted around the circumference.

= 0 No individual point plotting. <u>Do not</u> input individual point plotting flags. (If K_{11} = 0, then K_{13} must be 0.)

= "number" There is individual point plotting. Input the individual point plotting flags for "number" points. See individual point plotting flags.

K_{13} Specifies the size of the increment to the angle θ for the individual point plotting.

= 0 Set $\Delta\theta$ = 5 degrees.

= "number" Calculate $\Delta\theta$.

$\Delta\theta$ = 180/"number"

However, the minimum value of $\Delta\theta$ is two degrees. In either case, begin with θ = 0 degrees and finish with θ = 180 degrees.

K_{14} Specifies the number of load levels for which load plotting flags should be input.

= 0 No plotting. Do not input load plotting flags.

= "number" There is plotting. Input the load plotting flags for "number" loadings. See load plotting flags

LIMITATIONS

$1 \leq$ number ≤ 10

More detailed descriptions of the following phases may be found in the Output definition: separate harmonic results, combined harmonic results, normal plotting, and individual point plotting.

5. Segment Plotting Flags. (If $K_{11} = 0$, this card must not be included in the data deck.)

FORMAT

L_1	L_2	L_3	L_4	L_5	L_6	L_7

(7I10)

L_I= Flag indicating whether or not information should be plotted for the Ith segment.

= 0 Do not plot the information for this segment.

= 1 Do the normal plotting for this segment.

> 1 Plot only forces vs θ for the specified individual points in this segment.

6. Individual Point Plotting Flags. (If $K_{12} = 0$, these cards must not be included in the data deck.)

FORMAT

M_1	MM_1	M_2	MM_2	M_3	MM_3	M_4	MM_4	M_5	MM_5
M_6	MM_6	M_7	MM_7	M_8	MM_8	M_9	MM_9	M_{10}	MM_{10}

(10I5)

M_I The number of the segment containing the point at which forces vs θ are to be plotted.

MM_I Point number in the segment given by M_I above at which forces vs θ are to be plotted.

If these cards are included, one or two cards must be input, depending on the number of points to be plotted. For example, if five points are to be plotted, only one card should be input. The segment plotting flags for each segment containing a point to be plotted must be non-zero.

LIMITATIONS

$1 \leq I \leq 10$

7. Load Plotting Flags. (If $K_{14} = 0$ these cards must not be included in the data deck.) These flags control the option of plotting information at a particular load level.

FORMAT

N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}

(10I5)

N_I = 0 Do not plot information at "I^{th}" load level.
= 1 Do plot information at "I^{th}" load level.

LIMITATIONS

$1 \leq I \leq 10$ Only ten load levels may be plotted in one run.

8. Restart Options. The following options provide alternate means of controlling the flow of the program.

FORMAT

JJ_1	JJ_2	JJ_3	JJ_4	JJ_5	JJ_6	JJ_7

(7I10)

JJ_1 = 0 Read input data and continue.
= 1 Terminate execution after reading input data.

JJ_2 = 0 Process geometry and continue.

= 1 Terminate execution after performing geometry calculations.

JJ_3 = 0 First run of this problem.

= 1 This is a restart case. See Part D of the input data.

JJ_4 = 0 This is not an "update" case, but can be a restart case if JJ_3 equals one. If JJ_3 equals zero, JJ_4 must be zero.

= 1 This is an "update" case. The governing equations of equilibrium will be rebuilt using the solution vectors for all harmonics in the mounted prior solution tape. If JJ_4 equals one, JJ_3 must also equal one. Note that the matrix scale factors must not be input in an "update" case. Both "update" and "restart" cases are described in Section 2.3.5.

JJ_5 Not used.

JJ_6 Not used.

JJ_7 Not used.

9. Convergence Criterion Data. This data provides the user with the following options concerning the solution method.

FORMAT

JL_1	A_1	A_2

(I10,2F10.0)

JL_1 The number of complete harmonic loop iterations that will be performed on one load level before execution is stopped (normally JL_1 = 8).

A_1 = "number" The convergence criteria is based on comparing the incremental solution, for any harmonic M, with the summed solution for $\theta = 0$, i.e.,

$$\beta = \frac{\Delta Y_M}{\sum_M Y_M}$$

If $\beta < A_1$, then the solution is assumed to have converged (normally A_1 = .02).

A_2 Must be set equal to 1.0.

LIMITATIONS

(a) $JL_1 > 0$

(b) $A_1 > 0$

(c) $A_2 = 1.0$

2.3.3 Leading and Trailing Boundary Conditions

Each harmonic requires four leading and four trailing boundary conditions. Each boundary condition is input on a separate card. As Figure 2.3 shows, the leading edge boundary conditions for all harmonics must be input before the trailing edge boundary conditions. The boundary condition numbers are shown in Table 2.1.

1. Leading Edge Boundary Conditions.

FORMAT

JK_1	JK_2	A_1	A_2

(2I10,2F10.0)

JK_1 = The harmonic value

JK_2 = The boundary condition number

A_1 = The boundary condition value

A_2 = The increment to the boundary condition

LIMITATIONS

$1 \leq JK_2 \leq 16$

2. Trailing Edge Boundary Conditions.

FORMAT

JL_1	JL_2	B_1	B_2

(2I10,2F10.0)

Table 2.1 Boundary Condition Input Definitions

Number	Boundary Condition Definition
1	$U_M = a_1$
2	$V_M = a_2$
3	$W_M = a_3$
4	$\omega_{\theta_M} = a_4$
5	$\delta_{r_M} = V_M \cos\phi + W_M \sin\phi = a_5$
6	$\delta_{y_M} = V_M \sin\phi - W_M \cos\phi = a_6$
7	$\overline{N}_{\phi\theta_M} = a_7$
8	$N_{\phi_M} = a_8$
9	$\overline{Q}_{\phi_M} = a_9$
10	$M_\phi = a_{10}$
11	$N_{R_M} = N_{\phi_M} \cos\phi + \overline{O}_{\phi_M} \sin\phi = a_{11}$
12	$N_{Y_M} = N_{\phi_M} \sin\phi - \overline{O}_{\phi_M} \cos\phi = a_{12}$
13	$M_M = \pi r^2 (N_{\phi_M} \sin\phi - \overline{O}_{\phi_M} \cos\phi) + \pi r\, M_{\phi_M} = a_{13}$
14	$O_M = \pi r (N_{\phi_m} \cos\phi + \overline{O}_{\phi_M} \sin\phi) + \pi r\, \overline{N}_{\phi\theta_M} = a_{14}$
15	$V_M \cos\phi + W_M \sin\phi + U_M = a_{15}$
16	$\frac{1}{r} (V_M \sin\phi - W_M \cos\phi) - \omega_\theta = a_{16}$

JL_1 = The harmonic value

JL_2 = The boundary condition number

B_1 = The boundary condition value

B_2 = The increment to the boundary condition

LIMITATIONS

$1 \leq JL_2 \leq 16$

2.3.4 Segment Data

The segment data consists of the geometry data, the load data and the elastic support data for the discontinuity following the segment. Note that the geometry data is harmonic independent, but the load data and the elastic support data are harmonic dependent. Therefore, the load data and the elastic support data must be input for all harmonics.

Figure 2.5 shows the order of the segment data. The detailed format descriptions are considered in the following three parts: geometry data, load data, and elastic support data.

Before considering the three parts of the segment data, the following comments are in order.

In the following format descriptions, the segment number and harmonic value occur on most of the cards. These two items are used to check the order of the input data. The following paragraphs describe the conditions which these variables must satisfy.

The segment numbers must be positive, contiguous integers with values less than or equal to seven. For example, if five segments were specified, the segment numbers would be one, two, three, four and five. Whenever the segment number appears, it is compared with an internal counter to check this condition.

The harmonic values must correspond to the harmonic list with respect to both order and value.

If the above conditions are not met, an error message is printed, the remainder of the input data is read, and the case is terminated.

1. The geometry data consists of three cards per segment.

(a) First card. Specifies the interval sizes for this segment.

FORMAT

I_1	I_2	A_1	A_2	A_3	A_4

(2I10,4F10.0)

I_1 The segment number.

I_2 The number of intervals in this segment.

A_1 The number of leading intervals in this segment.

A_2 The number of trailing intervals in this segment.

A_3 The size of the first interval in this segment. This value may be omitted if $A_1 = 0$.

A_4 The size of the last trailing interval. This value may be omitted if $A_2 = 0$.

LIMITATIONS

$1 \leq I_1 \leq 7$
$2 \leq I_2 \leq 73$
$A_1 \geq 0$
$A_2 \geq 0$
$A_3 \geq 0$
$A_4 \geq 0$

(b) Second card. Specifies the segment geometry.

FORMAT

J_1	B_1	B_2	B_3	B_4	B_5	B_6

(I10,6F10.0)

J_1 = The segment number

B_1 = The "X" coordinate at the first point of the segment.

B_2 = The "Y" coordinate at the first point of the segment.

B_3 = The "X" coordinate at the last point of the segment.

B_4 = The "Y" coordinate at the last point of the segment.

B_5 = The "Y" component of the eccentricity between this segment and the following segment (e_y).

B_6 = The "R" component of the eccentricity between this segment and the following segment (e_r).

(c) Third Card. The thickness and material properties may vary linearly between the first and last point of the segment.

FORMAT

K_1	C_1	C_2	C_3	C_4	C_5	C_6

(I10,6F10.0)

K_1 = Segment number.

C_1 = The value of the thickness at the first point of the segment.

C_2 = The value of the thickness at the last point in the segment.

C_3 = The value of Young's modulus at the first point of this segment.

C_4 = The value of Young's modulus at the last point of this segment.

C_5 = The value of Poisson's ratio at the first point of this segment.

C_6 = The value of Poisson's ratio at the last point of this segment.

LIMITATIONS

None of C_1 - C_6 may equal zero.

2. Surface Load Data. The surface load data for one segment consists of four cards for each harmonic. The loading may vary linearly between the first and last point of the segment.

(a) First Card. The surface load data at the first point of this segment.

FORMAT

J_1	J_2	B_1	B_2	B_3	B_4	B_5

(2I10, 5F10.0)

J_1 = The segment number.

J_2 = The harmonic value.

B_1 = The value of the circumferential loading ($\overline{X}$) at the first point of the segment.

B_2 = The value of the meridional loading ($\overline{Y}$) at the first point of the segment.

B_3 = The value of the normal loading ($\overline{Z}$) at the first point of the segment.

B_4 = The value of the radial loading ($\overline{R}$) at the first point of the segment.

B_5 = The initial value of the axial loading ($\overline{a}$) at the first point of the segment.

(b) Second Card. The surface load data at the last point of this segment.

FORMAT

K_1	K_2	C_1	C_2	C_3	C_4	C_5

(2I10, 5F10.0)

K_1 = The segment number.

K_2 = The harmonic value.

C_1 = The value of the circumferential loading ($\overline{X}$) at the last point of the segment.

C_2 = The value of the meridional loading ($\overline{Y}$) at the last point of the segment.

C_3 = The value of the normal loading ($\overline{Z}$) at the last point of the segment.

C_4 = The value of the radial loading ($\overline{R}$) at the last point of the segment.

C_5 = The value of the axial loading ($\overline{a}$) at the last point of the segment.

(c) Third Card. The increments to the surface load data at the first point of this segment.

FORMAT

L_1	L_2	D_1	D_2	D_3	D_4	D_5

(2I10, 5F10.0)

L_1 = The segment number.

L_2 = The harmonic value.

D_1 = The increment to the value of the circumferential loading $(\overline{X})$ at the first point of the segment.

D_2 = The increment to the value of the meridional loading $(\overline{Y})$ at the first point of the segment.

D_3 = The increment to the value of the normal loading $(\overline{Z})$ at the first point of the segment.

D_4 = The increment to the value of the radial loading $(\overline{R})$ at the first point of the segment.

D_5 = The increment to the value of the axial loading $(\overline{a})$ at the first point of the segment.

(d) Fourth Card. The increments to the surface load data at the last point of this segment.

FORMAT

M_1	M_2	E_1	E_2	E_3	E_4	E_5

(2I10, 5F10.0)

M_1 = The segment number.

M_2 = The harmonic value.

E_1 = The increment to the value of the circumferential loading $(\overline{X})$ at the last point of the segment.

E_2 = The increment to the value of the meridional loading $(\overline{Y})$ at the last point of the segment.

E_3 = The increment to the value of the normal loading $(\overline{Z})$ at the last point of the segment.

E_4 = The increment to the value of the radial loading ($\overline{R}$) at the last point of the segment.

E_5 = The increment to the value of the axial loading ($\overline{a}$) at the last point of the segment.

3. Elastic Support and Discrete Load Data. This data is for the discontinuity following this segment.

(a) First Card. The discrete loads for the discontinuity following this segment.

FORMAT

N_1	N_2	F_1	F_2	F_3	F_4

(2I10,4F10.0)

N_1 = Segment number.

N_2 = Harmonic value.

F_1 = The starting value of the applied, discrete meridional moment (M_ϕ).

F_2 = The starting value of the applied, discrete radial force (N_R).

F_3 = The starting value of the applied, discrete axial force (N_Y).

F_4 = The starting value of the applied, discrete shear force ($N_{\phi\theta}$).

(b) Second Card. The load increments to the discrete loads for the discontinuity following this segment.

FORMAT

M_1	M_2	G_1	G_2	G_3	G_4

(2I10,4F10.0)

M_1 = Segment number.

M_2 = Harmonic value.

G_1 = The increment to the applied, discrete meridional moment (M_ϕ).

G_2 = The increment to the applied, discrete radial force (N_R).

G_3 = The increment to the applied, discrete axial force (N_Y).

G_4 = The increment to the applied, discrete shear force ($N_{\phi\theta}$).

(c) Third Card. The C.G. offset for the discontinuity following this segment.

FORMAT

N_1	N_2	H_1	H_2	H_3

(2I10,3F10.0)

N_1 = Segment number.

N_2 = Harmonic value.

H_1 = Support radius (R_s).

H_2 = Axial component of the eccentricity between the trailing point of the previous segment and the C.G. of the ring (e_y^s).

H_3 = Radial component of the eccentricity between the trailing point of the previous segment and the C.G. of the ring (e_r^s).

(d) Fourth, fifth and sixth cards. The elastic support stiffness coefficients for the discontinuity following this segment.

FORMAT

IJ_1	IJ_2	P_1	P_2	P_3	P_4	P_5

(2I10,5F10.0)

P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}

(7F10.0)

P_{13}	P_{14}	P_{15}	P_{16}

(4F10.0)

IJ_1 = Segment number.

IJ_2 = Harmonic value.

P_I = "I^{th}" stiffness coefficient ($1 \leq I \leq 16$)
($P_1 = C_1$, etc., see Section 1.3.3 for the definition of the C's)

2.3.5 Restart Data

The program has a restart capability. Hence, the program may be used to determine the solution to a specified number of load increments, stopped so that results may be studied, and restarted at a new load level. To restart the program, the tape instructions given in Section 2.6.6 must be followed and the initial data deck must be modified as follows:

1. All data pertaining to the loads on the shell must be changed so that the "starting" values correspond to the new load level that the user wishes to consider. The loading increment magnitudes may also be changed.

2. There are two kinds of restart options.

   (a) "Normal Restart" - If the program is to be restarted using the previously generated "L + U" tape then the scale factors for these matrices must be input. The scale factors for each harmonic are printed in the output data of each run. These scale factors <u>must</u> be copied and input on the following cards:

   FORMAT

I	A_1	A_2	A_3	A_4	(I10,4E15.8)
	A_5	A_6	A_7	A_8	(10X,4E15.8)
	A_9	A_{10}	A_{11}	A_{12}	(10X,4E15.8)

   I = Harmonic value

   A_J = The "J^{th}" scale factor.

   Figure 2.5 gives the order of these scale factors. For this restart option the "L + U" is mounted on logical unit 09 and the prior solution tape is mounted on logical unit 03.

(b) "Update Restart" - If the program is to be restarted and a new "L + U" tape is to be generated, then the scale factors must not be input.

For this restart option the prior solution tape is mounted on logical unit 03 and a scratch tape is mounted on logical unit 09.

3. The proper restart flags must also be set.

NOTE: The program may also have to be restarted when the solution has not converged in the specified maximum number of iterations. If this should occur, it is usually best to use the "update restart" option.

2.4 Program Output

2.4.1 Introduction

This section describes the output of the program. The program output consists of the following three parts: printed output, plotted output, and tape output.

2.4.2 Printed Output

This section describes the information which is printed by the program.

1. Input Data. The input data is always printed for each case. It is printed in the same fashion as the input cards were read.

2. Geometry Calculations (Optional). Depending on output options one, two, and three, the following items can be printed for each point of each segment.

   a. Geometry calculations including

arc-length	S
radius	r
length	Y
	sin (ϕ)
	cos (ϕ)

   b. Central differences $1./(s_{i+1}-s_i)$

   c. Physical characteristics

Young's modulus	E
thickness	H
Poisson's ratio	μ
extensional stiffness	D
bending stiffness	K

3. The Matrix of the Governing Equations of Equlibrium (Optional). Depending on output option four, the matrix of the governing equations of equilibrium and the right hand vector for the first special iteration can be printed at each point for all harmonics.

The amount of output can be estimated by the following equation

number of lines = (number of special iterations + number of harmonics)
times the number of points in the shell
times 42 lines per point.

For example, for a case with one -hundred points, six harmonics, and two special iterations, the number of lines printed is 33,600. It is suggested that this option not be exercised.

4. Matrix Scale Factors. On a first run of a case and an "update" of a case, the matrix scale factors will be printed for each harmonic. The twelve numbers for each harmonic must be punched and input on cards for each restart of the case in which they were printed. Section 2.3.5 of the input data contains the format details.

5. "β" Values. The "β" values reflect the convergence progress of the solution for each load level. The "β" values are printed after the solution for each of the harmonics has been incremented and additionally after the convergence criterion has been satisfied. The information printed is defined in the following: The five maximum "β" values and the point in the shell at which they occurred are printed for each harmonic. The "β" calculation is defined in the convergence criterion in Section 2.3.2.

6. Convergence at each Load Level. The following describes what information can be printed and in what manner it can be printed.
   a. What information at each point.
      (1) Point identification. The first line printed will contain the following.

Variable	Heading
1. point number in segment	POINT
2. segment number	SEGMENT
3. harmonic value	HARMONIC

Variable	Heading
4. thickness at this point	THICKNESS
5. radius at this point	RADIUS
6. arc length between first point and this point	S
7. arc length between this point and next point	ARC
8. value of angle θ	THET

For separate harmonic printing, THET = 0.

For combined harmonic printing, HARMONIC will be the value of last harmonic considered.

(2) Displacements and rotations (optional). The following information will be printed if specified by output option seven.

Variable	Heading
1. circumferential displacement	U
2. meridional displacement	V
3. normal displacement	W
4. circumferential rotation (ω_θ)	OMEGA(T)
5. meridional rotation (ω_ϕ)	OMEGA(P)
6. normal rotation (ω)	OMEGA
7. radial displacement (δ_r)	DELTA(R)
8. axial displacement (δ_y)	DELTA(Y)

(3) Forces and moments (optional). The following information will be printed if specified by output option seven.

Variable	Heading
1. in plane shear force ($\overline{N}_{\phi\theta}$)	NBAR(P-T)
2. meridional force (N_ϕ)	N(P)
3. circumferential force (N_θ)	N(T)
4. radial force (N_r)	N(R)
5. axial force (N_y)	N(Y)

Variable	Heading
6. normal shear force ($\overline{Q}_\phi$)	QBAR(P)
7. meridional bending moment (M_ϕ)	M(P)
8. circumferential bending moment (M_ϕ)	M(T)
9. shear moment ($M_{\phi\theta}$)	M(P-T)

For combined harmonic printing the following stresses will be considered part of the forces printing.

Variable	Heading
1. meridional stress (outside surface)	SIGMA(P) +
2. meridional stress (inside surface)	SIGMA(P) -
3. circumferential stress (outside surface)	SIGMA(T) +
4. circumferential stress (inside surface	SIGMA(T) -
5. shear stress (outside surface)	SIGMA(P-T)+
6. shear stress (inside surface)	SIGMA(P-T)-
7. effective stress (outside surface)	SIGMA(EFF)+
8. effective stress (inside surface)	SIGMA(EFF)-

(4) For each segment the maximum effective stress and its location will be printed.

(5) For each load level, the number of plots made and the estimated plotting time will be printed.

b. How the information will be printed at each point. The following options are available.

(1) Separate harmonic printing. The information in a. will be printed for each harmonic.

(2) Combined harmonic printing. The information in a. will be printed after summing the variables over all harmonics in the following manner:

$$\text{Variable}_{(\text{combined})} = \sum_{M} \text{Variable}_{M} \times \begin{Bmatrix} \sin(M\theta) \\ \cos(M\theta) \end{Bmatrix}$$

The sine or the cosine of $M\theta$ will be used depending on each variable

The values of θ used are input by output option nine.

(c) What points are printed. Output option eight specifies which of the points will be printed.

(d) What load levels will be printed. Output option ten specifies which load levels will be printed.

7. Information Printed for all Load Levels. After all load levels have converged and have been printed, the following information which was saved for each load level will be printed.

The axial displacement for the combined harmonic printing at the last point of the shell for $\theta = 0$ degrees.

8. Abnormal Terminations. Printing for the following situations has been provided:

a. Divergence. If one of the four unknowns u, v, w or ω_θ in the incremental solution should become greater in absolute value than one hundred, an appropriate error message will be printed, the incremental solution will be printed, and the case will be terminated.

b. No convergence. If a solution for a particular load level has not converged after "II" iterations (input), an error message is printed, the output options given below are set, the information is printed, and the case is terminated.

(1) Print both displacements and forces

(2) Perform separate harmonic printing and combined harmonic printing for $\theta = 0^\circ$ and $\theta = 180^\circ$

(3) Print every point

(4) Perform no plotting

2.4.3 Plotting Output.

This section describes the information which is plotted by the program.

All plotting performed will be for five variables (circumferential force, N_θ, circumferential bending moment, M_θ, in plane shear force, $\overline{N}_{\phi\theta}$, meridional force, N_ϕ, and meridional bending moment, M_ϕ,) in a combined harmonic mode.

Two types of plotting are available:

1. The variable plotted against arc length for the values of the angle theta specified by output option nine.

   A maximum of five curves will be put on each grid, and the maximum number of values of theta considered is 181; i.e., values of theta ranging between zero degrees and one hundred eighty degrees, in increments of one degree. The arc length points are specified by output option eight.

2. The variable is plotted around the circumference (against θ) at a particular point in a particular segment specified by the individual point plotting flags. The increments of theta are specified by output option thirteen with the minimum increment being two degrees.

"Normal" plotting is part 1. and part 2. if any points to be plotted are in the segment.

"Individual" point plotting is part 2. only.

Other plotting options available are described in the following:

a. Each load level will or will not be plotted depending on the input load plotting flags.

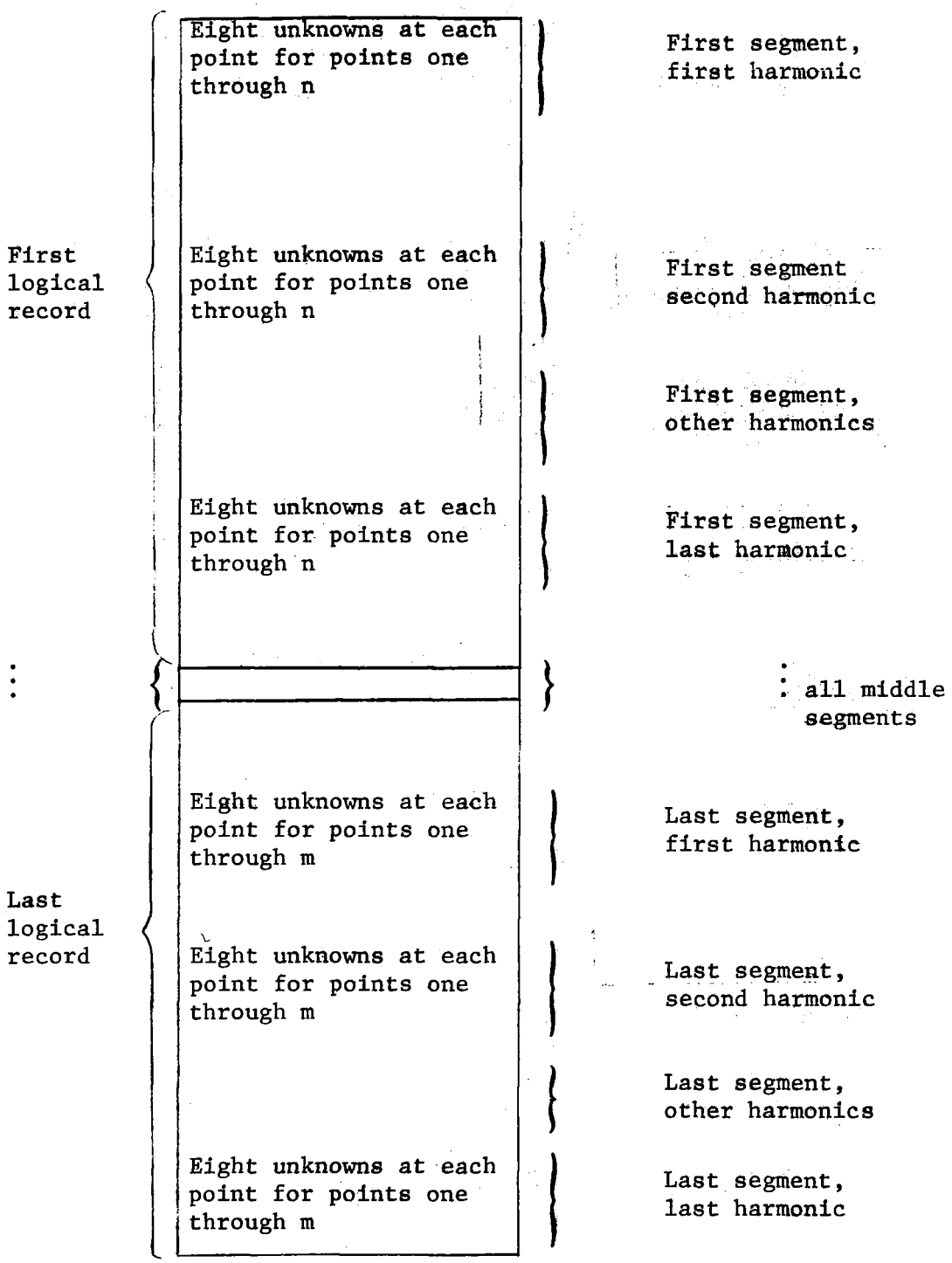
b. Each segment will or will not be plotted depending on the input segment plotting flags.

2.4.4 Tape Output

This section describes the tape formats for those tapes which must be saved for a restart problem.

The tape formats for the prior solution tape (unit 04) and the matrix solver tape (unit 09) are shown in Figures 2.7 and 2.8.

These tapes are used for a restart of a particular problem.



1. Each segment is written as one logical record.
2. The eight unknowns at each point are u, v, w, ω_θ, $\overline{N}_{\phi\theta}$, N_θ, $\overline{Q}_\phi$, M_ϕ

Figure 2.7 Prior Solution Tape Format

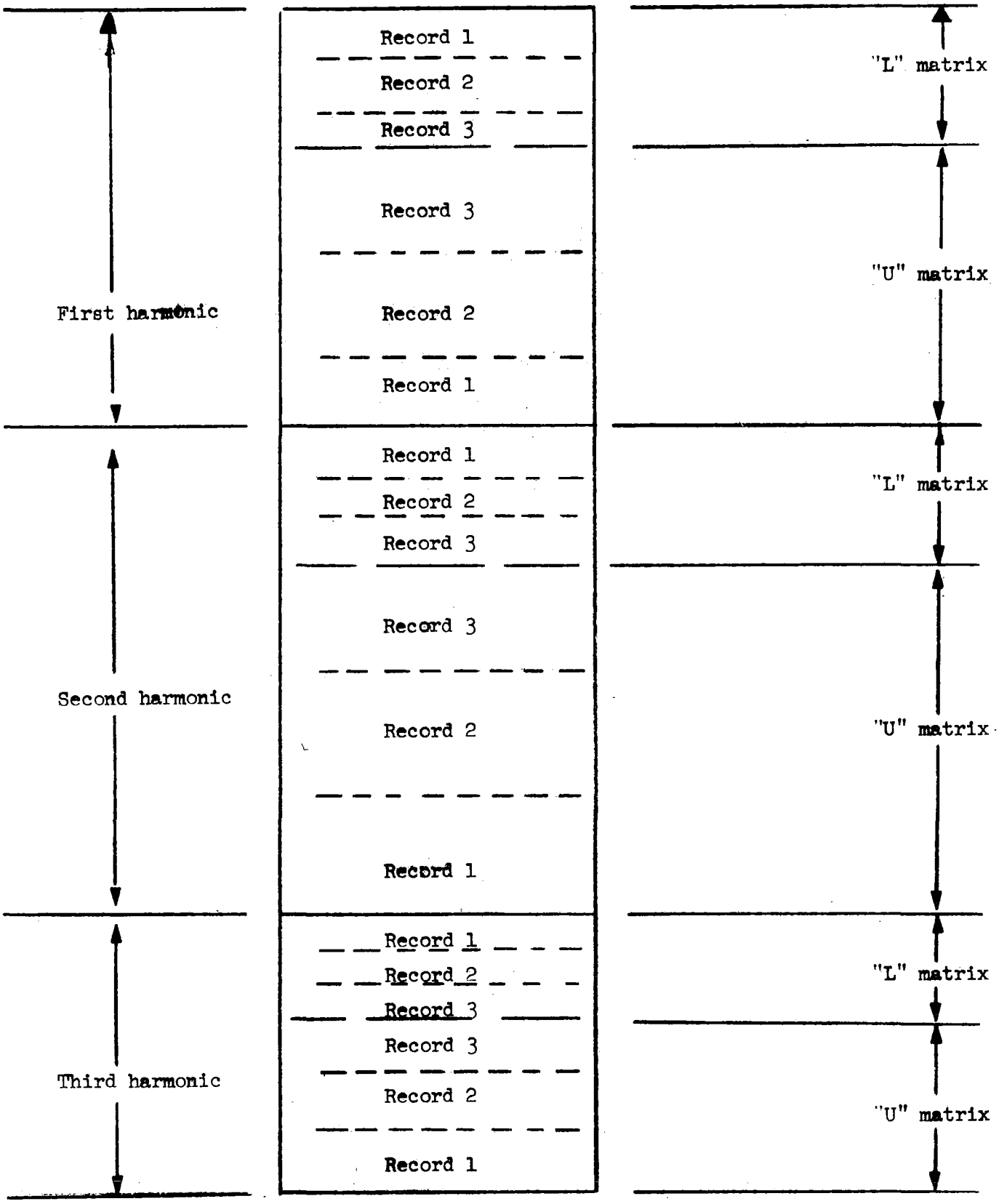


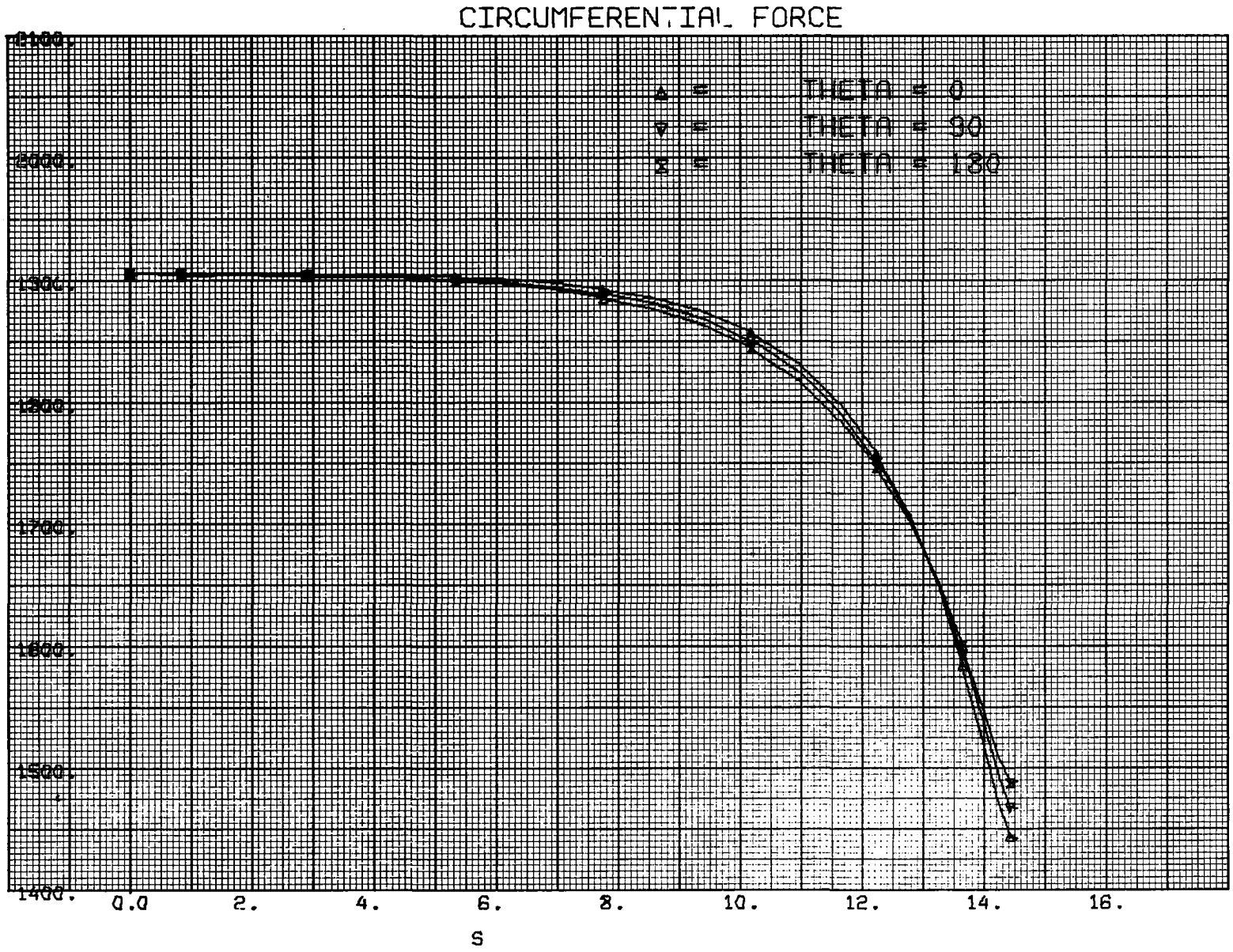
Figure 2.8 "L + U" Tape Format for Case with Three Harmonics and Three Records (35 $\leq$ number of points in case $\leq$ 50)

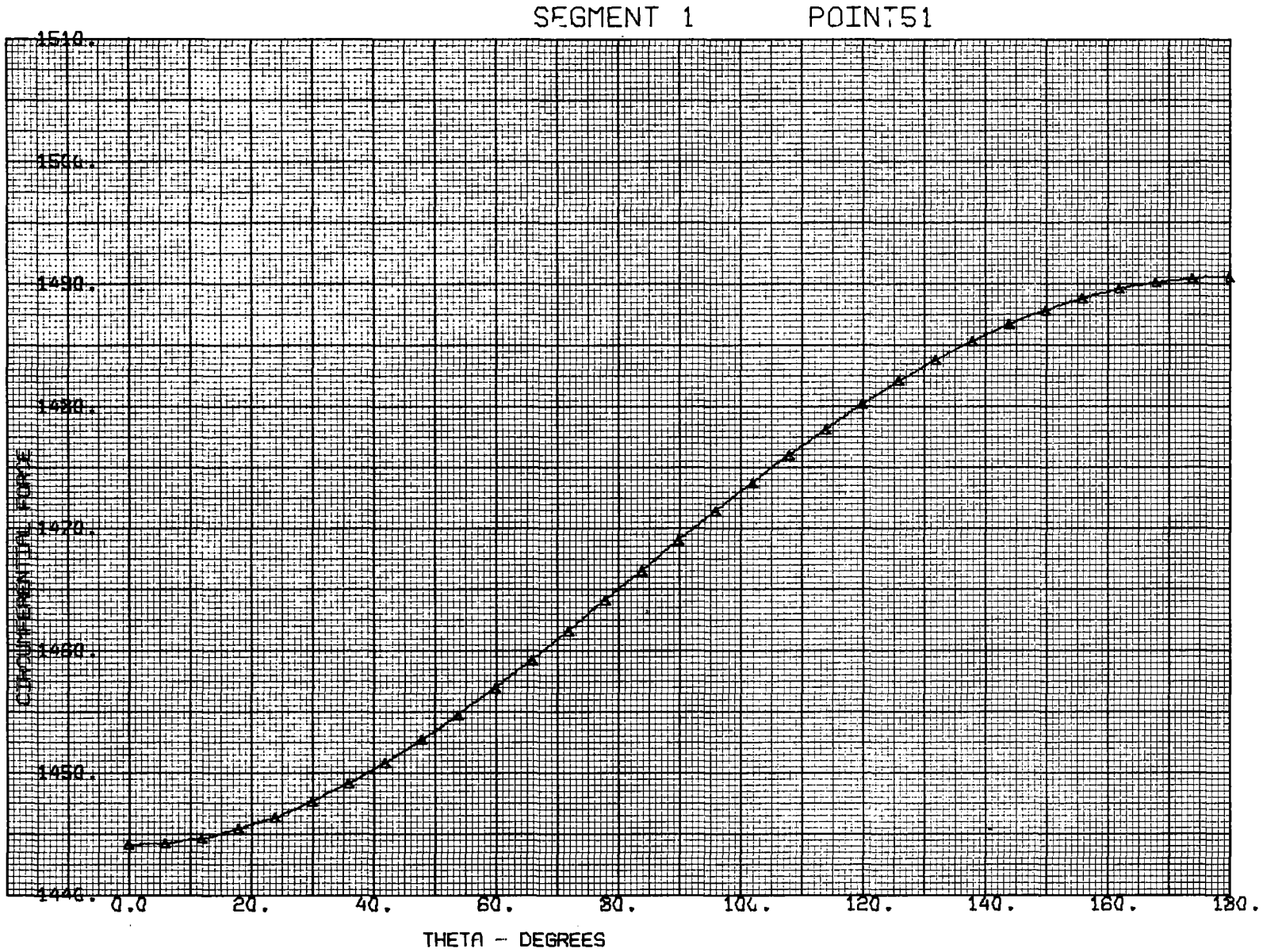
2.5 Sample Problem

To demonstrate the use of the computer program, the input and output data for a typical problem are presented. The problem solved is the section of the Atlas missile shown in Figure 1.4 and described in section 1.4.

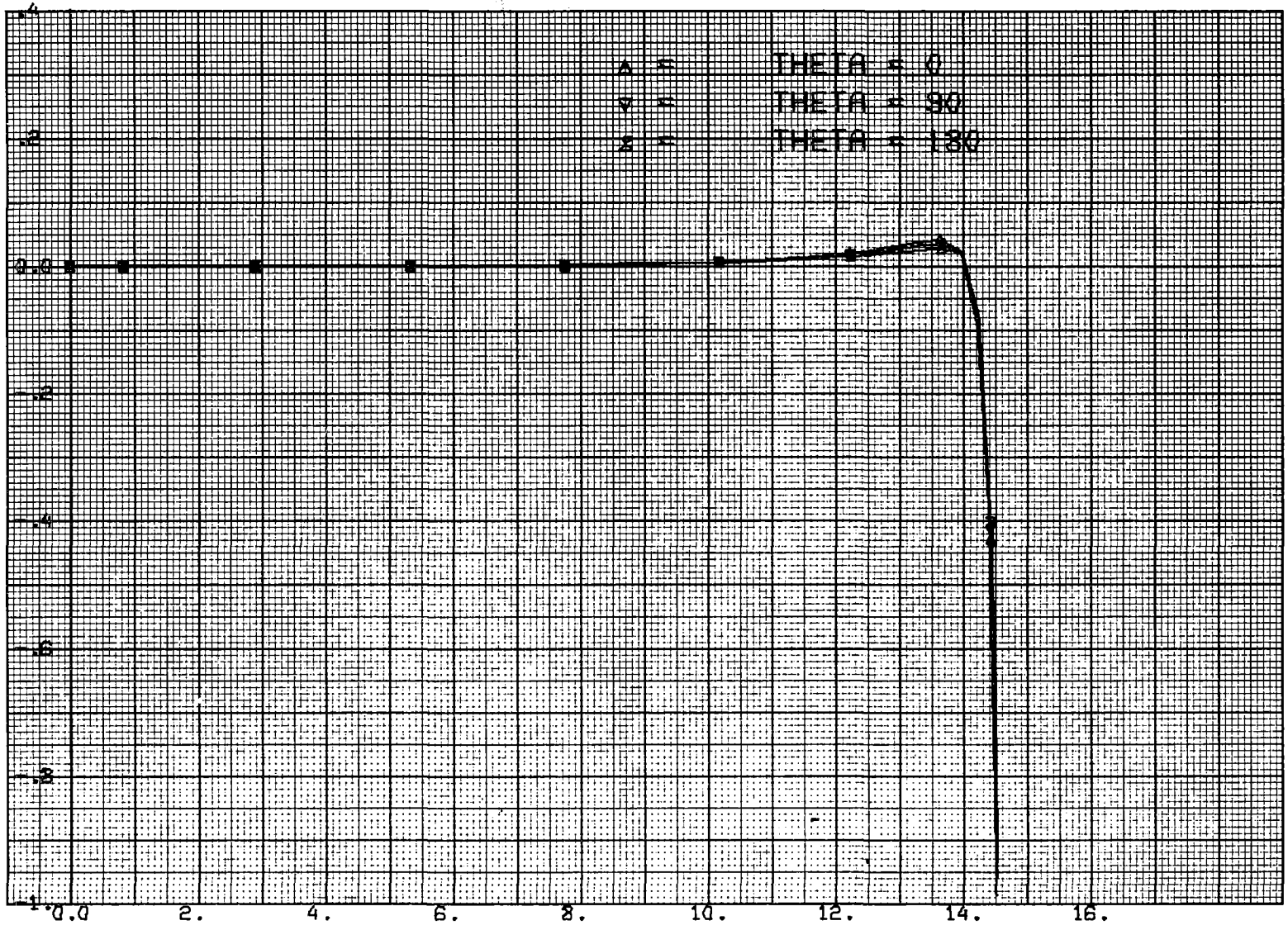
The loading considered for this sample problem is an internal pressure of 31.70 p.s.i., an axisymmetric meridional force of 519 lb/in and a bending moment of 1.0×10^6 in-lb. For this value of bending moment only the first three harmonics needed to be considered (i.e., M = 0,1,2). The mathematical model for this problem is shown in Figure 1.4b. A careful review of the input data should serve as a guide for using the program to solve other problems.

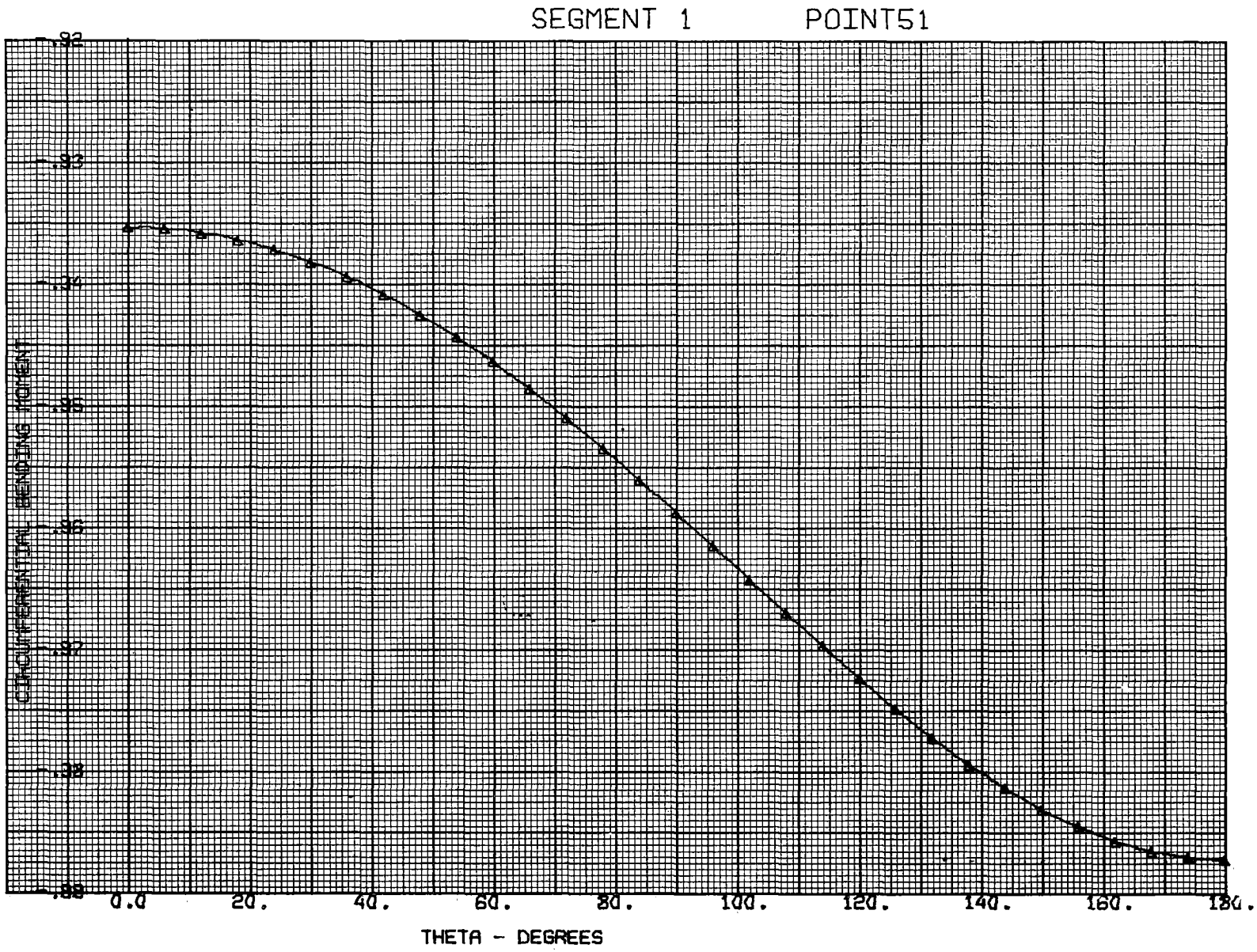
The printed results for this problem include displacements, rotations, forces, moments and stresses for every other pivotal point and for three values of the circumferential angle. Sample plotting results are also shown for segment 1. These data samples are presented on pages 115 to 133. A complete description of the output data format is given in Section 2.4.

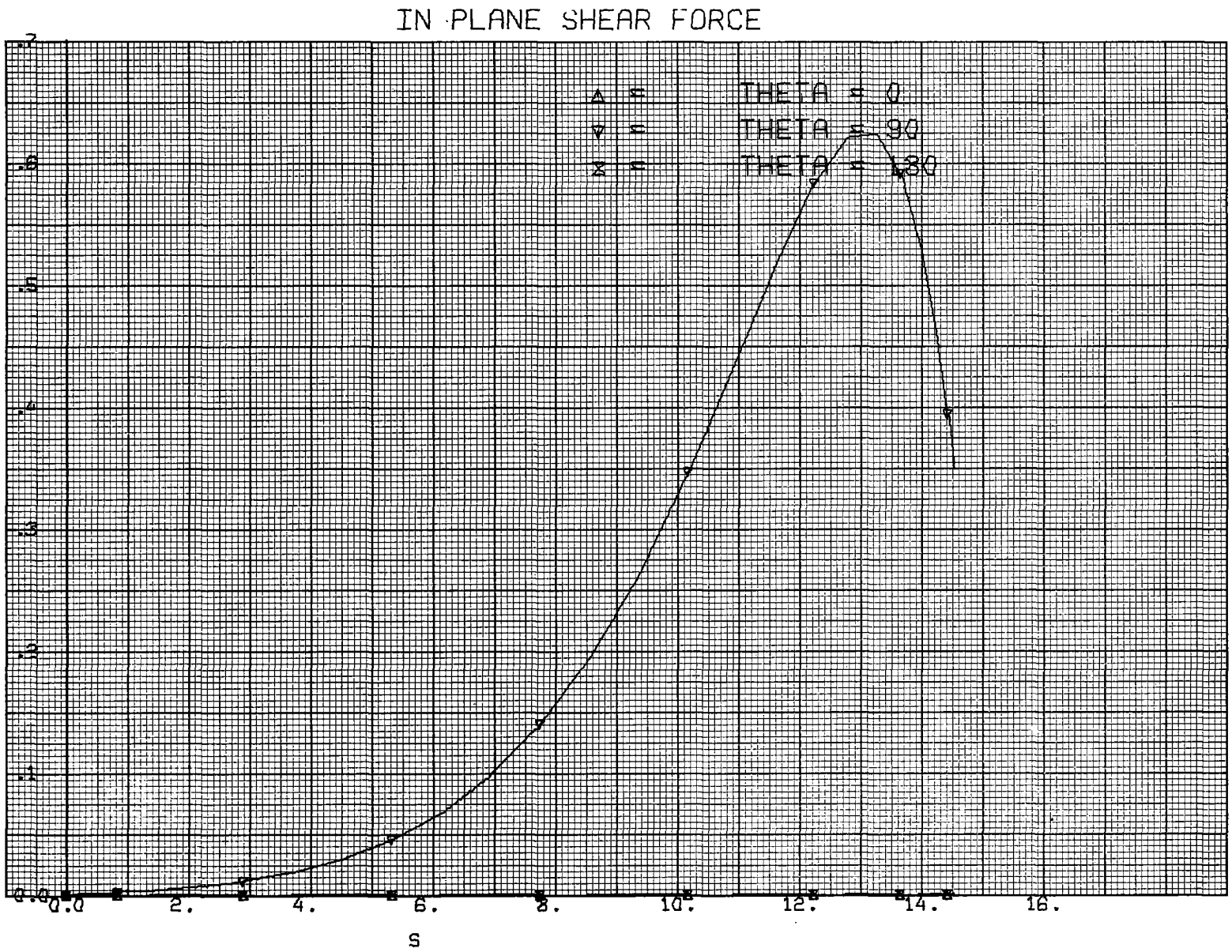

CIRCUMFERENTIAL FORCE
▲ = THETA = 0
▼ = THETA = 90
✱ = THETA = 130
2000.
1900.
1800.
1700.
1600.
1500.
1400.
0.0
2.
4.
6.
8.
10.
12.
14.
16.
S

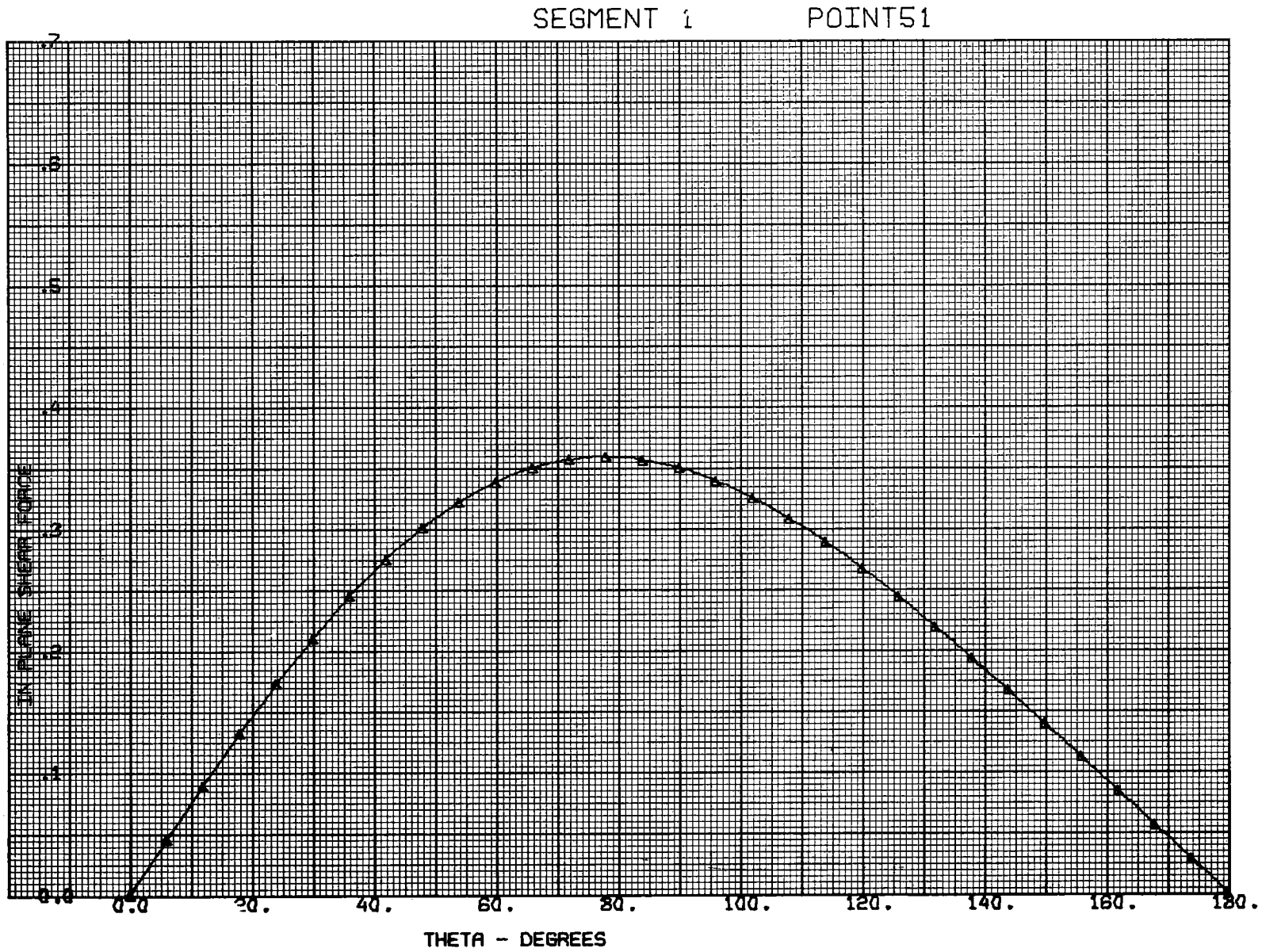

SEGMENT 1 POINT51
1510.
1500.
1490.
1480.
1470.
1460.
1450.
1440.
CIRCUMFERENTIAL FORCE
0.0
20.
40.
60.
80.
100.
120.
140.
160.
180.
THETA - DEGREES

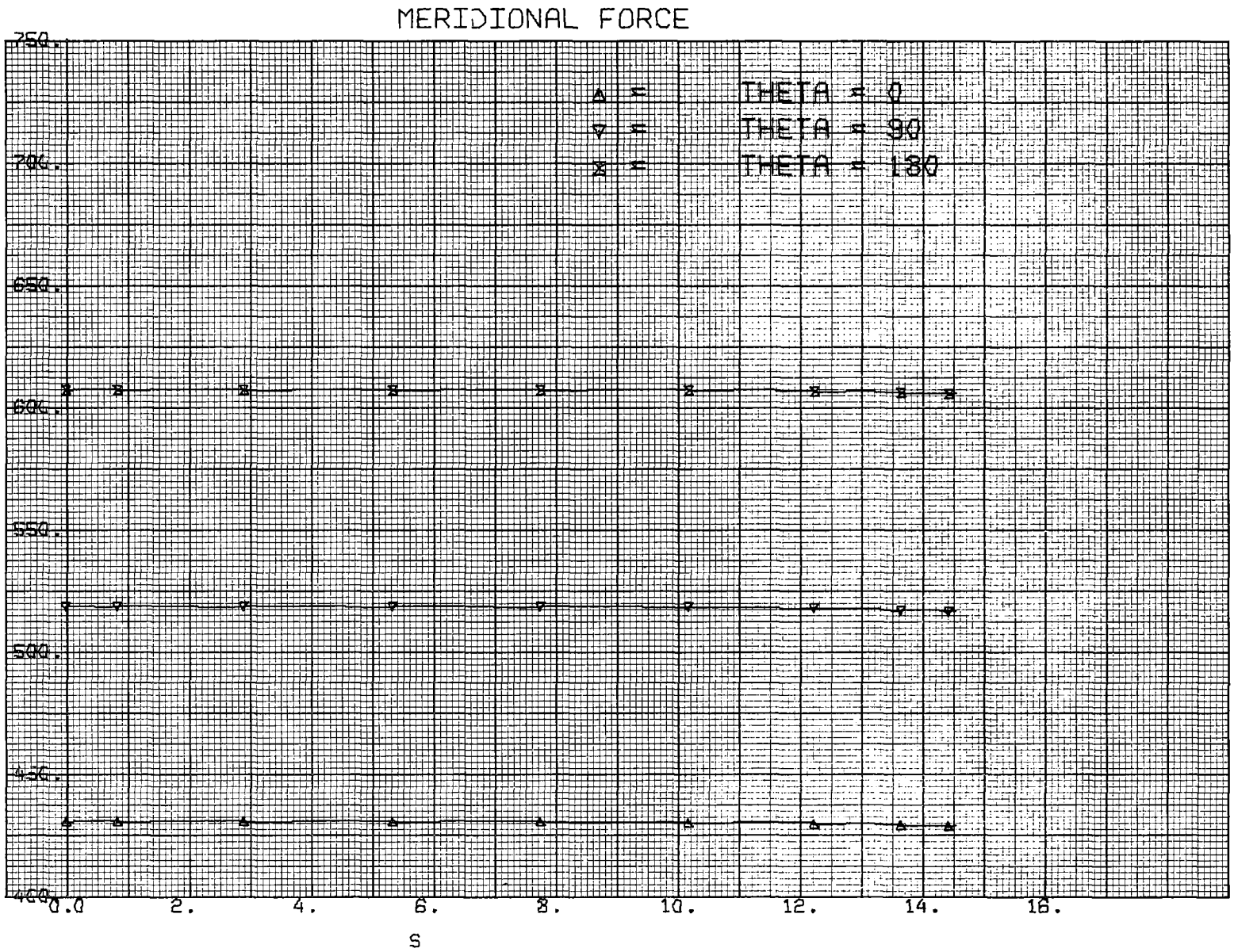
CIRCUMFERENTIAL BENDING MOMENT

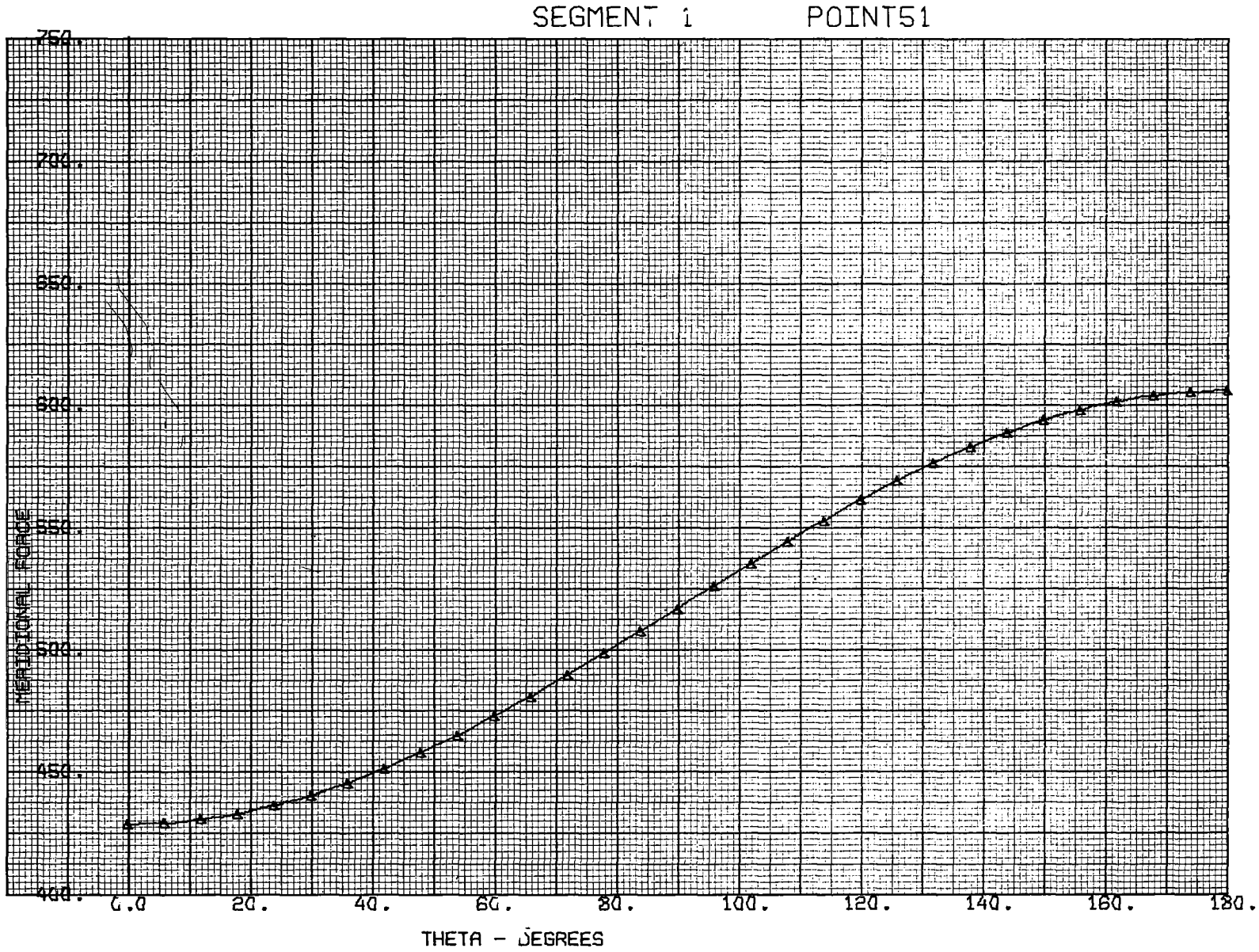



SEGMENT 1 POINT51
CIRCUMFERENTIAL BENDING MOMENT
-.92
-.93
-.94
-.95
-.96
-.97
-.98
-.99
0.0
20.
40.
60.
80.
100.
120.
140.
160.
180.
THETA - DEGREES

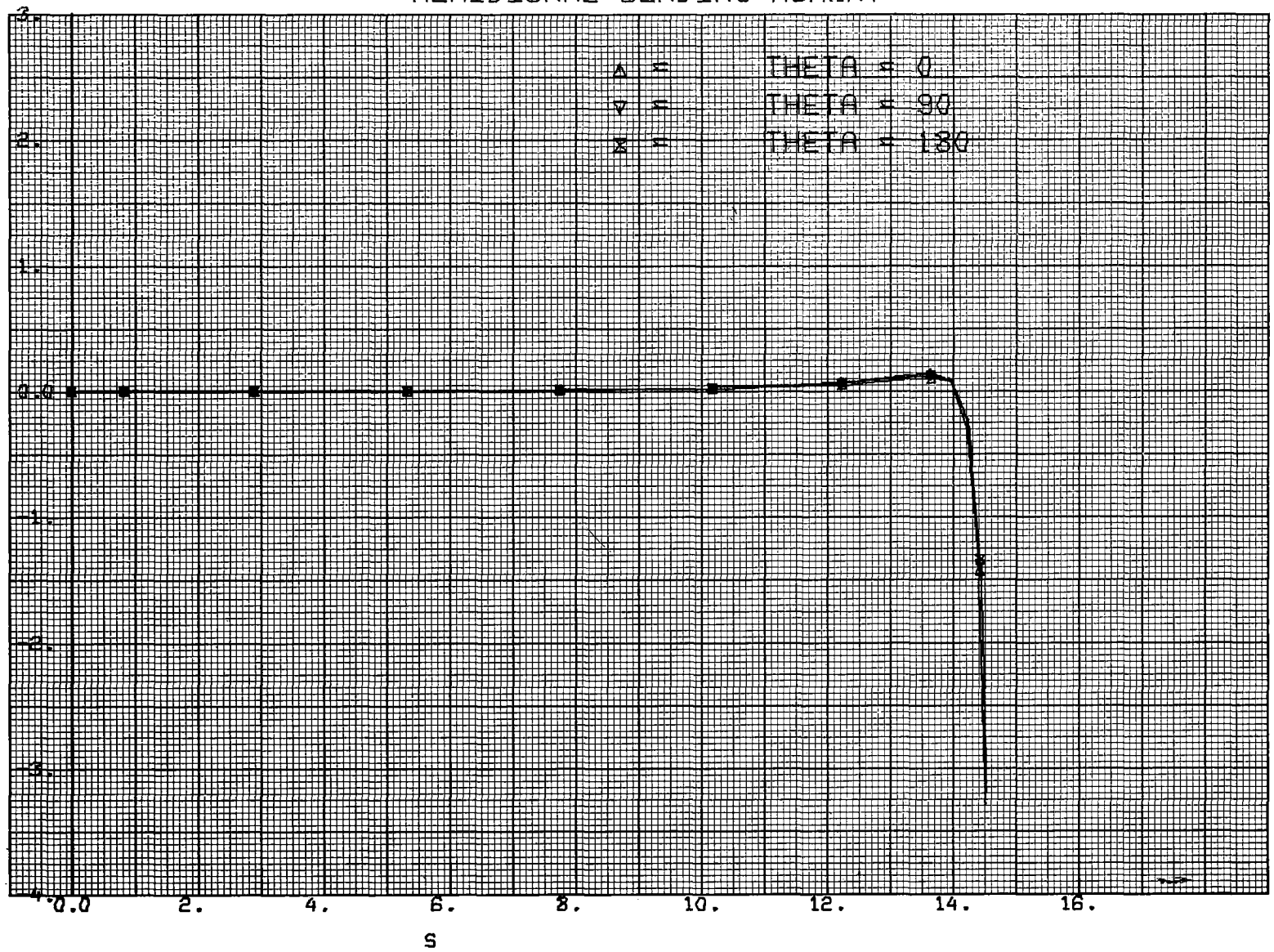

IN PLANE SHEAR FORCE
THETA = 0
THETA = 90
THETA = 180
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
2.
4.
6.
8.
10.
12.
14.
16.
S

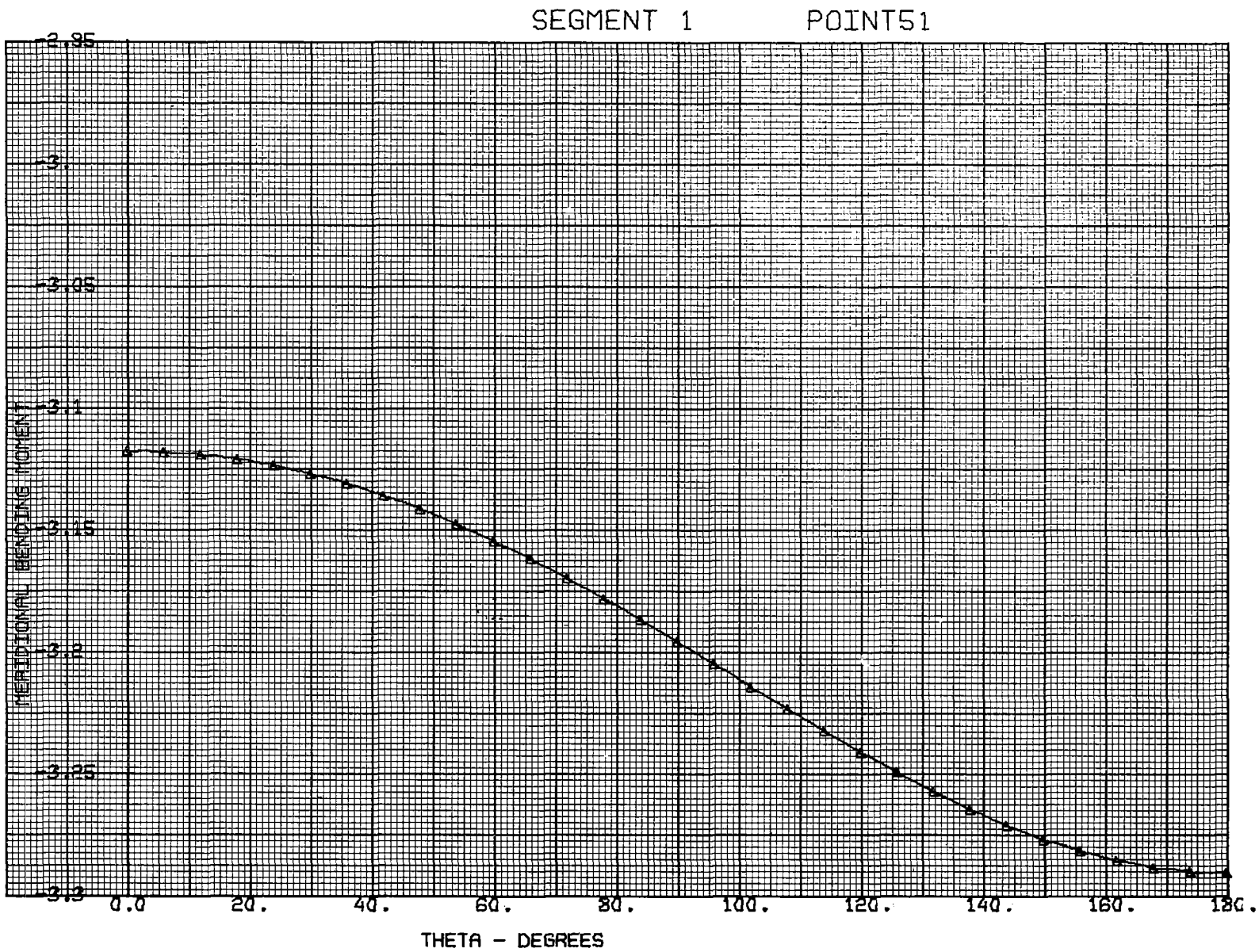

SEGMENT 1 POINT51
IN PLANE SHEAR FORCE
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
20.
40.
60.
80.
100.
120.
140.
160.
180.
THETA - DEGREES


MERIDIONAL FORCE
THETA = 0
THETA = 90
THETA = 130
750.
700.
650.
600.
550.
500.
450.
400.
0.0
2.
4.
6.
8.
10.
12.
14.
16.
S


SEGMENT 1 POINT51
HORIZONTAL FORCE
750.
700.
650.
600.
550.
500.
450.
400.
0.0
20.
40.
60.
80.
100.
120.
140.
160.
180.
THETA - DEGREES

MERIDIONAL BENDING MOMENT




SEGMENT 1 POINT51
MERIDIONAL BENDING MOMENT
-3.05
-3.1
-3.15
-3.2
-3.25
0.0
20.
40.
60.
80.
100.
120.
140.
160.
180.
THETA - DEGREES

DATE

NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 1 OF 7

PRIORITY

KEYPUNCHED BY 42

VERIFIED BY

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–74	75–80
	TEST CASE,	THREE SEGMENTS,	THREE HARMONICS					CØMM
3	3	1	3					FLAG
0	1	2						HARM
1 1	1 0	0 2	3 2	2 1	3 1	90 1		IØPT
1	0	0						S.PF
1 51								IPPF
1								L.PF
0	0	0	0	0	0	0		RØPT
4	.02	1.0						CCR
0	1	0						L.BC 0
	2							
	4							
	9							
1	2							1
	4							
	7							
	9							
2	2							2
	4							
	7							

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NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 2 OF 7

PRIORITY

KEYPUNCHED 42 86

VERIFIED BY

2	9	0					L.BC	2
0	1	0					T.BC	0
	3	.237						
	4	0						
	8	519						
1	1	0						1
	3	0						
	13	-1.0E 6						
	16	0						
2	1							2
	2							
	3							
	4							
1	50	10	20	.05	.05		BEØM	1
1	60	14.895	60	.345	0	-.009		
1	.017	.017	2.7E 7	2.7E 7	.3	.3		
1	0			31.69			LØAD	0
				31.69				

SYSTEMS 704 REV. 12-60

DATE

NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 3 OF 7

PRIORITY

KEYPUNCHED 42 46

VERIFIED BY

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–74	75–78	79–80
1	0							E.SD	0
		59.9825	-.15	-.0175					
		0	0	0	0	0			
0	0	0	0	0	40.5	0			
0	0	0	.303864						
1	1							LØAD	1
								E.SD	
		59.9825	-.15	-.0175					
		40.5	0	40.5	0	0			
8.4456 -5	0	-5.06588-3	40.5	0	40.5	0			
0	0	-5.06588-3	0	.303864					
1	2							LØAD	2

SYSTEMS 7[illegible] REV. 12-66

DATE

NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 4 OF 7

PRIORITY

KEYPUNCHED BY 42 46

VERIFIED BY

1	2						E.SD	2
		59.9825	-.15	-.0175				
		162	0	8.1	0	0		
1.35129-3	0	-202.6E-4	81	0	40.5	0		
0	-202.6E-4	0	.303864					
2	14						GEØM	2
	59.9991	.345	59.9991	-.345	0	-8.5-3		
	.035	.035	2.7E 7	2.7E 7	.3	.3		
	0			31.69			LØAD	0
				31.69				
							E.SD	
		60	0	9.0-3				
		0	0	0	0	0		
0	0	0	0	0	40.5	0		
0	0	0	.303864					
2	1						LØAD	1

SYSTEMS 709 REV. 12-66

DATE

NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 5 OF 7

PRIORITY 42

KEYPUNCHED BY

VERIFIED BY

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–74	75–80
2	1							LØAD 1
								E.SD
		60	0	9.0-3				
		40.5	0	40.5	0	0		
8.4456 -5	0	-5.06588-3	40.5	0	40.5	0		
0	-5.06588-3	0	.303864					
2	2							LØAD 2
								E.SD
		60	0	9.0-3				
		162	0	81	0	0		
1.35129-3	0	-202.6E-4	81	0	40.5	0		
0	-202.6E-4	0	303864					
3	70	20	20	0.5	.05			GEØM 3

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DATE

NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 6 OF 7

PRIORITY

KEYPUNCHED BY

VERIFIED BY

3	59.9825	-.345	59.9825	-29.445	0	0	GEØM	3
	.018	.018	2.7E 7	2.7E 7	.3	.3		
	0			31.69			LØAD	0
				31.69				
							E.SD	
0	0							
0	0							
3	1						LØAD	1
							E.SD	

SYSTEMS 708 REV. 12-66

DATE

NAME

PROBLEM NO.

NO. OF CARDS

COMPUTATION AND DATA REDUCTION CENTER

80 COLUMN FREE KEY PUNCH FORM

PAGE 7 OF 7

PRIORITY

KEYPUNCHED BY

VERIFIED BY

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–74	75–78	79–80
0	0							E.SD	1
0	0							↓	↓
3	2							LØAD	2
↓	↓							↓	↓
								↓	↓
								E.SD	2
↓	↓							↓	↓
0	0							↓	↓
0	0							↓	↓

SYSTEMS 708 REV. 12-66

The following 77 pages of preprinted computer data are numbered separately within this report.

SEGMENT 3

NO. INTERVALS = 70 NO. LEADING INT. = 20. NO. TRAILING INT. = 20.
SIZE LEADING INT. = 5.0000E-02
SIZE TRAILING INT. = 5.0000E-02
LEADING (X, Y) = (5.998250E 01,-3.450000E-01)
TRAILING (X, Y) = (5.998250E 01,-2.944500E 01)
F(Y) = 0. E(R) = 0.

	E	H	MU
INITIAL	2.7000000E 07	1.8000000E-02	3.0000000E-01
FINAL	2.7000000E 07	1.8000000E-02	3.0000000E-01

HARMONIC = 0

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	3.1690000E 01	-0.	-0.
FINAL	-0.	-0.	3.1690000E 01	-0.	-0.

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 6.0000E 01
ECCENTRICITY(C.G. OFFSET)
F(Y) = 0.
E(R) = 9.0000E-03

STIFFNESS COEFFICIENTS-C(I)

2	2	0.	-0.
2	3	0.	-0.
2	4	0.	-0.

SEGMENT DATA

SEGMENT 1

NO. INTERVALS = 50 NO. LEADING INT. = 10. NO. TRAILING INT. = 20.
SIZE LEADING INT. = 5.0000E-02
SIZE TRAILING INT. = 5.0000E-02
LEADING (X, Y) = (6.000000E 01, 1.489500E 01)
TRAILING (X, Y) = (6.000000E 01, 3.450000E-01)
E(Y) = 0. E(R) =-9.000000E-03

	E	H	MU
INITIAL	2.7000000E 07	1.7000000E-02	3.0000000E-01
FINAL	2.7000000E 07	1.7000000E-02	3.0000000E-01

HARMONIC = 0

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	3.1690000E 01	-0.	-0.
FINAL	-0.	-0.	3.1690000E 01	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 5.9982E 01
ECCENTRICITY(C.G. OFFSET)
E(Y) =-1.5000E-01

F(R) =-1.7500E-02

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	0.
2	0.
3	0.
4	0.
5	0.
6	0.
7	0.
8	0.
9	0.
10	0.
11	4.050000E 01
12	0.
13	0.
14	0.
15	0.
16	3.038640E-01

HARMONIC = 1

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 5.9982E 01

ECCENTRICITY(C.G. OFFSET)

E(Y) =-1.5000E-01
E(R) =-1.7500E-02

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	4.050000E 01
2	0.
3	4.050000E 01
4	0.
5	0.
6	8.445600E-05
7	0.
8	-5.065880E-03
9	4.050000E 01
10	0.
11	4.050000E 01
12	0.
13	0.
14	0.
15	-5.065880E-03
16	0.

HARMONIC = 2

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 5.9982E 01
ECCENTRICITY(C.G. OFFSET)
E(Y) =-1.5000E-01
E(R) =-1.7500E-02

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	1.620000E 02
2	0.
3	8.100000E 01
4	0.
5	0.
6	1.351290E-03
7	0.
8	-2.026000E-02
9	8.100000E 01
10	0.
11	4.050000E 01
12	0.
13	0.
14	-2.026000E-02
15	0.
16	3.038640E-01

SEGMENT 2

NO. INTERVALS = 14 NO. LEADING INT. = -0. NO. TRAILING INT. = -0.
SIZE LEADING INT. =-0.
SIZE TRAILING INT. =-0.
LEADING (X, Y) =(5.999910E 01, 3.450000E-01)
TRAILING (X, Y) = (5.999910E 01,-3.450000E-01)
E(Y) = 0. E(R) =-8.500000E-03

	E	H	MU
INITIAL	2.7000000E 07	3.4999999E-02	3.0000000E-01
FINAL	2.7000000E 07	3.4999999E-02	3.0000000E-01

HARMONIC = 0

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	3.1690000E 01	-0.	-0.

FINAL	-0.	-0.	3.1690000E 01	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

	MP(0)	NR(0)	NY(0)	NPT(0)
	-0.	-0.	-0.	-0.
INCREMENT TO				
	MP(0)	NR(0)	NY(0)	NPT(0)
	-0.	-0.	-0.	-0.

SUPPORT RADIUS = 6.0000E 01

ECCENTRICITY(C.G. OFFSET)

E(Y) = 0.

E(R) = 9.0000E-03

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	0.
2	0.
3	0.
4	0.
5	0.
6	0.
7	0.
8	0.
9	0.
10	0.
11	4.050000E 01
12	0.
13	0.
14	0.
15	0.
16	3.038640E-01

HARMONIC = 1

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 6.0000E 01
ECCENTRICITY(C.G. OFFSET)
E(Y) = 0.
E(R) = 9.0000E-03

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	4.050000E 01
2	0.
3	4.050000E 01
4	0.
5	0.
6	8.445600E-05
7	0.
8	-5.065880E-03
9	4.050000E 01
10	0.
11	4.050000E 01
12	0.
13	0.
14	-5.065880E-03
15	0.
16	3.038640E-01

HARMONIC = 2

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 6.0000E 01
ECCENTRICITY(C.G. OFFSET)
E(Y) = 0.
E(R) = 9.0000E-03

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	1.620000E 02
2	0.
3	8.100000E 01
4	0.
5	0.
6	1.351290E-03
7	0.
8	-2.026000E-02
9	8.100000E 01
10	0.
11	4.050000E 01
12	0.
13	0.
14	-2.026000E-02
15	0.
16	3.038640E-01

OVERLAY ORIGIN CARDS AND ASSIGNED LINK NUMBERS

```
$ORIGIN     FIRST.SYSUT3                IS LINK   1. PARENT LINK IS   0
$ORIGIN     FIRST.SYSUT3                IS LINK   2. PARENT LINK IS   0
               INCLUDE       FATN
$ORIGIN     FIRST.SYSUT3                IS LINK   3. PARENT LINK IS   0
$ORIGIN     FIRST.SYSUT3                IS LINK   4. PARENT LINK IS   0
               INCLUDE       FBST
$ORIGIN     FIRST.SYSUT3                IS LINK   5. PARENT LINK IS   0
$ORIGIN     FIRST.SYSUT3                IS LINK   6. PARENT LINK IS   0
               INCLUDE       FLOG.FXPF.FXP3
$ORIGIN     FIRST.SYSUT3                IS LINK   7. PARENT LINK IS   0
```

```
                    * MEMORY MAP *

SYSTEM                                  00000 THRU  02717
FILE BLOCK ORIGIN                       02720
FILES        1.     UNIT50
             2.     UNIT02
             3.     UNIT03
             4.     UNIT06
             5.     UNIT08
             6.     UNIT12
             7.     UNIT13
             8.     UNIT14
             9.     UNIT15
FILE LIST ORIGIN                        03074
PRE-EXECUTION INITIALIZATION            03114
CALL ON OBJECT PROGRAM                  03175
OBJECT PROGRAM                          03202 THRU  36715

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

  0  MCNIX   03202      /COMAA / 03204     EVEN    03203    /COMBB / 03206     EVEN    03205    /COMCC / 03210
                        ///    /(44610)    EVEN    03211     ......  03310 *
     FDICX   03322       EVEN    03323     FDIC    03603
     GETMX   03700       EVEN    03701     GETM    04444
     PADR    04514       .PADR   04514
     UN50    04515       .UN50.  04515
     GEOO    04516       GEOBOT  04516     GEOEOT  04516
     .LINK   04517      /.LDT   / 04517   /.LRECT/ 04527    /.LVEC / 04571
     .LINCT  04607       .MXLIN  04607 *   .MAXP   04607 *   .JPUN   04607 *
     .LXCON  04614       .LXSTR  04614     .LXSTP  04614    /EXOUT / 04630     .LXERR  04631     .LXOUT  04677
                         IBEXIT  04704 *   .LXRTN  04704     .DBCLS  05060 *   .LXARG  05257     .LO     05302
                         .ARG    05304     .CLSE   05311     .LFBL   05312 *   .LUNB   05313
     .IODEF  05322       .DEFIN  05322     .ATTAC  05326 *   .CLOSE  05330     .OPEN   05332     .READ   05334
                         .WRITE  05336     .BSR    05346     .READR  05356 *   .RELES  05360 *   .LAREA  05371
                         .LFBLK  05407     .AREA1  05424     .LUNBL  05432 *   .ENTRY  05436     .GOA    05467
                         .GO     05473     .DERR   05507     .NOPXT  05510     .COMXT  05512     .FX34   05534
     .IOCSE  05541       GEOEOT (04516)    GEOBOT (04516)
     STLFIN  10057       .FIN.   10057 *   .FIN    10057
```

.LOVRY	10163	.LOVRY	(10163)	.LDT	(04517)	.LRECT	(04527)	.LVEC	(04571)		
.LXSL	10542	.LXSEL	10542	.LXIND	10702	.LXDIS	10705	.LXFLG	10706	.LTCH	10707
.FPTRP	11011	.FFPT.	11011 *	FTRP	11135 *	/PKSP /	11233 *	.FPOUT	11246	.FPARG	11254
		/.COUNT/	11255 *	OVFLOW	11321 *						
.ERAS.	11330	E.1	11330	E.2	11331	E.3	11332	E.4	11333		
XIT	11334	EXIT	11334	.EXIT.	11334	XITFLG	11337				
FXEM	11340	.FXEM.	11340	FXEFLG	11715 *	.FXOUT	11742	.FXARG	11750	BLANKS	12036
		NOP	12037 *	SYSONF	12040	/FXCN /	12042 *	/.OPTW./	12045 *	NTERR	12052
		TERR	12063 *	AERR	12114 *	ERROR	12133	WHCH	12207 *	RESUME	12244
		/EOFILE/	12245								
FOUT	12253	.FOUT.	12253								
FCNV	12631	.FCON.	12631	.FCNV.	12652	.ENDFS	12661	.CNVSW	12663	.FDX1	12667
		.FDX2	12670	.DBC	12672	.DBC10	13022	.DBC20	13050	.DDSW	13060
		.FIXSW	13063	.DDBC	13121	.DDFIX	13231	.DDRS1	13337	.DDRS2	13341
		.D1	13344	.D2	13346	.ANPT	13423	.ONPT	13440	.LNTP	13514
		.AOUT	13563	.OOUT	13574	.LOUT	13623	.DFLT	13633	.FLT	14063
		.FXFL1	14170	.FXD	14174	.FXFL2	14177	.FXFL3	14203	.INTG	14207
		.TOPAC	14225	.WIDTH	14231	.FPACK	14236	.TEST	14237	.KOUNT	14272
		.LIST	14275	.DONE	14302	.OUTBF	14772	EVEN	14771	.CHAR	15224
		.FBDBF	15237	EVEN	15251	.DDDFL	15265	.DDFLG	15266	.WORD	15267
		.MOD	15270	.PEX	15271	.FEXP	15272	.DIG	15273	.DEXPN	15274
FIOB	15310	.FIOB.	15310	.FCNT	15417	.FBLT.	15515	.FBDT.	15537	.FRLR.	15565
		.FWLR.	15630	.FBIBF	15667	.FRITE	15761				
FIOS	15767	.FIOS.	15767	.REED	16130 *	.BIN	16131	.FCT	16132	.FCKS7	16134
FIOH	16215	.FIOH.	16215	.FFIL.	17062	.FRTN.	17110				
FSEL	17262	.FSEL.	17262	.FILR.	17267	.FRTB.	17276	.FRTD.	17304	.FILL.	17310
		.FCLS	17312	.FOPN	17316	REOF	17322	.TOUT.	17473		
FWRD	17502	.FWRD.	17502								
FWRB	17561	.FWRB.	17561								
FRDD	17612	.FRDD.	17612								
FRDB	17661	.FRDB.	17661								
STLPUN	17713	.FPUN	17713								
UNC2	20207	.UNC2.	20207								
UNC3	20210	.UNC3.	20210	.BUFSZ	20211						
UNC6	20214	.UNC6.	20214								
UNC8	20215	.UNC8.	20215								
UN12	20216	.UN12.	20216								
UN13	20217	.UN13.	20217								

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      UN14     20220      .UN14.   20220
      UN15     20221      .UN15.   20221
      FSCN     20222      COS      20222     SIN      20223
      FSQR     20416      SQRT     20416
      FEFT     20471      .FEFT.   20471
      FRWT     20567      .FRWT.   20567
      STLOUT   20664      .FOUT    20664
      .XCC.    20705      CC.1     20705     CC.2     20706     CC.3     20707     CC.4     20710
      //       44610

1     MON1X    20711     /COMAA /(03204)    /COMBB /(03206)    /COMCC /(03210)    ///    /(44610)    MON1     24031
      PDINX    24060      EVEN     24061     PDIN     24520
      BCONX    24620      EVEN     24621     BCON     25145

2     MON2X    20711     /COMAA /(03204)    ///    /(44610)    MON2     22366
      FATN     22407      ATAN2    22407     ATNQ     22407 *   ATAN     22410 *
      GEOMX    22641      GEOM     23132
      MESHX    23262      EVEN     23263     MESH     23702
      EHMUX    24000      EVEN     24001     EHMU     24104
      DANKX    24155      DANK     24347
      NRPRX    24451      NRPR     24617

3     MON3X    20711     /COMAA /(03204)    /COMCC /(03210)    /COM31 / 20712    /COM32 / 21112    /COM33 / 21116
                          EVEN     21115     /COM34 / 21126     EVEN     21125    /COM36 / 21130    EVEN     21127
                         ///    /(44610)     EVEN     23411     MON3     24265
      HARMX    24310     /COM31 /(20712)    /COM32 /(21112)    /COM33 /(21116)    /COM35 / 24312    EVEN     24311
                         ///    /(44610)     HARM     25453
      MISCX    25474     /COM32 /(21112)    /COM33 /(21116)    /COM35 /(24312)    /COM37 / 25476    EVEN     25475
                          MISC     25774
      ACADX    26115     /COM31 /(20712)    /COM32 /(21112)    /COM33 /(21116)    /COM34 /(21126)   /COM35 /(24312
                          ACAD     26246
      ACOEX    26306     /COM32 /(21112)     EVEN     26307     ACOE     27400
      MACOX    27670     /COM32 /(21112)    /COM33 /(21116)    /COM36 /(21130)    /COM37 /(25476)    EVEN     27671
                          MACO     31111
      GAMMX    31361     /COM32 /(21112)    /COM33 /(21116)    /COM35 /(24312)     GAMM     32036
      BETAX    32076     /COM32 /(21112)    /COM33 /(21116)    /COM35 /(24312)     EVEN     32077    BETA     33216
      KCOEX    33326     /COM31 /(20712)    /COM32 /(21112)     EVEN     33327     KCOE     33602
      EQUMX    33653     /COM31 /(20712)    /COM33 /(21116)    /COM35 /(24312)     EQUM     34123
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     BRHVX   34144    /COM32 /(21112)   /COM33 /(21116)   EVEN    34145    BRHV    34640

4    MCN4X   20711    /COMAA /(03204)   /COM41 / 20712    /COM42 / 20726   EVEN    20725    /COM43 / 2104
                      /COM44 / 21044    EVEN    21043     /COM45 / 21142   /COM49 / 21144   EVEN    2114
                      ///    /(44610)   EVEN    21145     MON4    23233
     FBST    23254     .FBST.  23254
     PRNXX   23470     EVEN    23471     PRNX    23665
     PRMYX   23723     PRMY    24130
     LANUX   24167    /COMAA /(03204)   /COM41 /(20712)   /COM42 /(20726)   /COM43 /(21040)   /COM44 /(2104
                      /COM45 /(21142)   /COM49 /(21144)   LANU    25277
     PELRX   25407    /COM41 /(20712)   /COM42 /(20726)   /COM44 /(21044)   PELR    25757
     BSUBX   26026    /COM41 /(20712)   /COM42 /(20726)   /COM44 /(21044)   /COM45 /(21142)   EVEN    2602
                       BSUB    26527
     MABTX   26605     MABT    30202     MABTU   30340
     RDCXX   30344     EVEN    30345     RDCX    30461
     MABLX   30515     MABL    31202     MABLU   31301
     MABBX   31305     MABB    31634     MABBU   31715

5    MCN5X   20711    /COMAA /(03204)   /COMBB /(03206)   /COMCC /(03210)   /COM51 / 20712   /COM52 / 2072
                       EVEN    20717    /COM59 / 20730    ///    /(44610)   MON5    22502
     TCCRX   22525    /COM51 /(20712)    TCCR    23124
     CNRHX   23174    /COMAA /(03204)   /COM51 /(20712)   /COM52 /(20720)   /COM53 / 23176   EVEN    2317
                      /COM54 / 23232    /COM55 / 23566    /COM56 / 23576   /COM58 / 24136   /COM59 /(2073
                      ///    /(44610)    CNRH    25440
     OMEGX   25461    /COM51 /(20712)   /COM52 /(20720)    OMEG    26317
     SDATX   26405    /COM51 /(20712)   /COM52 /(20720)   /COM53 /(23176)   /COM54 /(23232)   /COM56 /(2357
                       SDAT    27407
     PVALX   27521    /COM51 /(20712)   /COM52 /(20720)   /COM53 /(23176)   /COM54 /(23232)   /COM55 /(2356
                      /COM56 /(23576)    PVAL    30444
     LAMBX   30526    /COM52 /(20720)   /COM54 /(23232)   /COM55 /(23566)   /COM56 /(23576)   /COM58 /(2413
                       EVEN    30527     LAMB    31760
     SUMMX   32051    /COM58 /(24136)    SUMM    33123    SUMMU   33167
     BVECX   33172    /COM51 /(20712)   /COM52 /(20720)   /COM53 /(23176)   /COM56 /(23576)   /COM59 /(2073
                       EVEN    33173     BVEC    33634
     DVECX   33663    /COM51 /(20712)   /COM52 /(20720)   /COM53 /(23176)   /COM56 /(23576)   /COM57 / 3366
                      /COM58 /(24136)   /COM59 /(20730)    DVEC    35150
     KCOGX   35270    /COM52 /(20720)   /COM57 /(33664)   /COM58 /(24136)   EVEN    35271    KCOG    3556
     RANPX   35615    /COM51 /(20712)   /COM52 /(20720)   /COM53 /(23176)   /COM54 /(23232)   /COM55 /(2356
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                        /COM56 /(23576)   /COM59 /(20730)    RANP     36674

6  MON6X    20711      /COMAA /(03204)   /COM61 / 20712    /COM62 / 20720     EVEN     20717    /COM64 / 2073
                        EVEN     20727    /COM65 / 21020    /COM66 / 21036    /COM67 / 21064     EVEN     2106
                        /COM69 / 21070    /COM6A / 21116    /COM6B / 21134    /COM6C / 21146     EVEN     2114
                        /COM6D / 21152    /COM6E / 21154     EVEN     21153    /COM6F / 21156     EVEN     2115
                        ///     /(44610)   EVEN     21161    MON6     22363
   FMROX    22401      /COM61 /(20712)   /COM62 /(20720)   /COM63 / 22402    /COM64 /(20730)   /COM66 /(2103
                        /COM67 /(21064)    EVEN     22445    FMRO     23432
   SDAVX    23552      /COM61 /(20712)   /COM62 /(20720)   /COM63 /(22402)   /COM64 /(20730)   /COM67 /(2106
                        EVEN     23553    SDAV     24167    SDAVU    24274
   LANBX    24300      /COM63 /(22402)   /COM64 /(20730)   /COM65 /(21020)   /COM66 /(21036)    EVEN     2430
                        LANB     25052
   SUNNX    25121      /COM65 /(21020)    SUNN     25424    SUNNU    25467
   STRTX    25473      /COM61 /(20712)   /COM62 /(20720)   /COM69 /(21070)   /COM6B /(21134)   /COM6D /(2115
                        STRT     26062    STRTU    26071
   DISPX    26074      /COM61 /(20712)   /COM63 /(22402)   /COM64 /(20730)   /COM65 /(21020)   /COM66 /(2103
                        /COM67 /(21064)   /COM68 / 26076     EVEN     26075    /COM69 /(21070)   /COM6A /(2111
                        /COM6D /(21152)    EVEN     26141    DISP     26400    DISPU    26413
   FORCX    26416      /COM61 /(20712)   /COM62 /(20720)   /COM63 /(22402)   /COM64 /(20730)   /COM67 /(2106
                        /COM68 /(26076)   /COM69 /(21070)   /COM6A /(21116)   /COM6B /(21134)   /COM6D /(2115
                        /COM6F /(21156)    EVEN     26417    FORC     27054
   SUFPX    27076      /COM61 /(20712)   /COM69 /(21070)   /COM6A /(21116)   /COM6B /(21134)   /COM6C /(2114
                        /COM6D /(21152)   /COM6E /(21154)    EVEN     27077    SUFP     30375    SUFPU    3045
   IBCDFR   30463       IBCDFR (30463)
   PLOTX    30705       PLOT     31607
   CCP      31706       CCP     (31706)    CCP     (31706)
   FLOG     35610       ALOG10   35610    ALOG     35611
   FXPF     36014       EXP      36014
   FXP3     36135       .XP3.    36135
   SCAL     36262       SCAL    (36262)    EVEN     36441    EVEN     36457

7  MON7X    20711      ///     /(44610)    MON7     21252
   PRNYX    21270       EVEN     21271    PRNY     21476

I/O BUFFERS                    36716 THRU  44601
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UNUSED CORE 44602 THRU 44607

```
          TEST CASE, THREE SEGMENTS, THREE HARMONICS

 CASE DATA
 NO. OF SEGMENTS= 3      NO. OF HARMONICS= 3      NO. OF LOAD STEPS=  1      NO. M=0 ITERATIONS= 3
 HARMONIC VALUES
  M( 1) =     0
  M( 2) =     1
  M( 3) =     2

 OUTPUT OPTIONS
  OPT( 1) =  1
  OPT( 2) =  1
  OPT( 3) =  1
  OPT( 4) =  0
  OPT( 5) =  0
  OPT( 6) =  2
  OPT( 7) =  3
  OPT( 8) =  2
  OPT( 9) =  2
  OPT(10) =  1
  OPT(11) =  3
  OPT(12) =  1
  OPT(13) = 90
  OPT(14) =  1

      THETA INCREMENT = 90 DEGREES

 SEGMENT PLOT FLAGS
     SEGMENT        FLAG
        1             1
        2             0
        3             0

 INDIVIDUAL POINT PLOTTING
     SEGMENT      POINT
        1           51

      THETA INCREMENT =  2 DEGREES

 LOAD LEVEL PLOTTING FLAGS
```

LOAD LEVEL	FLAG
1	1

RESTART OPTIONS

ROPT(1) = 0
ROPT(2) = 0
ROPT(3) = 0
ROPT(4) = 0
ROPT(5) = 0
ROPT(6) = 0
ROPT(7) = 0

MAX. NO. OF ITERATIONS = 4 BETA(MAX) = 0.0200 CONVERGENCE FACTOR = 1.0000

BOUNDARY CONDITIONS

LEADING EDGE

HARMONIC	B.C. NO.	INITIAL VALUE	INCREMENT
0	1	0.	-0.
0	2	0.	-0.
0	4	0.	-0.
0	9	0.	-0.
1	2	0.	-0.
1	4	0.	-0.
1	7	0.	-0.
1	9	0.	-0.
2	2	0.	-0.
2	4	0.	-0.
2	7	0.	-0.
2	9	0.	-0.

TRAILING EDGE

HARMONIC	B.C. NO.	INITIAL VALUE	INCREMENT
0	1	0.	-0.
0	3	2.370000E-01	-0.
0	4	0.	-0.
0	8	5.190000E 02	-0.
1	1	0.	-0.
1	3	0.	-0.
1	13	-1.000000E 06	-0.
1	16	0.	-0.
2	1	0.	-0.

I	C(I)
1	4.050000E 01
2	0.
3	4.050000E 01
4	0.
5	0.
6	8.445600E-05
7	0.
8	-5.065880E-03
9	4.050000E 01
10	0.
11	4.050000E 01
12	0.
13	0.
14	-5.065880E-03
15	0.
16	3.038640E-01

HARMONIC = 2

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS = 6.0000E 01
ECCENTRICITY(C.G. OFFSET)
E(Y) = 0.
E(R) = 9.0000E-03

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	1.620000E 02
2	0.
3	8.100000E 01
4	0.
5	0.
6	1.351290E-03
7	0.
8	-2.026000E-02
9	8.100000E 01
10	0.
11	4.050000E 01
12	0.
13	0.
14	-2.026000E-02
15	0.
16	3.038640E-01

SEGMENT 3

NO. INTERVALS = 70 NO. LEADING INT. = 20. NO. TRAILING INT. = 20.

SIZE LEADING INT. = 5.0000E-02
SIZE TRAILING INT. = 5.0000E-02
LEADING (X, Y) = (5.998250E 01,-3.450000E-01)
TRAILING (X, Y) = (5.998250E 01,-2.944500E 01)
E(Y) = 0. E(R) = 0.

	E	H	MU
INITIAL	2.7000000E 07	1.8000000E-02	3.0000000E-01
FINAL	2.7000000E 07	1.8000000E-02	3.0000000E-01

HARMONIC = 0

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	3.1690000E 01	-0.	-0.
FINAL	-0.	-0.	3.1690000E 01	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS =-0.

ECCENTRICITY(C.G. OFFSET)

E(Y) =-0.

E(R) =-0.

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	-0.
2	-0.
3	-0.
4	-0.
5	-0.
6	0.
7	0.
8	-0.
9	-0.
10	-0.
11	-0.
12	-0.
13	0.
14	0.
15	-0.
16	-0.

HARMONIC = 1

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

INCREMENT TO

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.

FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

	MP(0)	NR(0)	NY(0)	NPT(0)
	-0.	-0.	-0.	-0.
INCREMENT TO				
	MP(0)	NR(0)	NY(0)	NPT(0)
	-0.	-0.	-0.	-0.

SUPPORT RADIUS =-0.
ECCENTRICITY(C.G. OFFSET)
E(Y) =-0.
E(R) =-0.

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	-0.
2	-0.
3	-0.
4	-0.
5	-0.
6	0.
7	0.
8	-0.
9	-0.
10	-0.
11	-0.
12	-0.
13	0.
14	0.
15	-0.
16	-0.

HARMONIC = 2

LOAD DATA

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.
INCREMENT TO					

	XBAR	YBAR	ZBAR	AXIAL	RADIAL
INITIAL	-0.	-0.	-0.	-0.	-0.
FINAL	-0.	-0.	-0.	-0.	-0.

ELASTIC SUPPORT DATA

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

INCREMENT TO

MP(0)	NR(0)	NY(0)	NPT(0)
-0.	-0.	-0.	-0.

SUPPORT RADIUS =-0.
ECCENTRICITY(C.G. OFFSET)
E(Y) =-0.
E(R) =-0.

STIFFNESS COEFFICIENTS-C(I)

I	C(I)
1	-0.
2	-0.
3	-0.
4	-0.
5	-0.
6	0.
7	0.
8	-0.
9	-0.
10	-0.
11	-0.
12	-0.
13	0.
14	0.
15	-0.
16	-0.

GEOMETRY

SEGMENT 1

PHI(DEGREES) = 90.000001
SIN(PHI) = 1.000000
COS(PHI) = 0.

POINT	S	R	Y
1	0.	6.000000E 01	1.489500E 01
2	4.999967E-02	6.000000E 01	1.484500E 01
3	1.354408E-01	6.000000E 01	1.475956E 01
4	2.563232E-01	6.000000E 01	1.463868E 01
5	4.126467E-01	6.000000E 01	1.448235E 01
6	6.044114E-01	6.000000E 01	1.429059E 01
7	8.316173E-01	6.000000E 01	1.406338E 01
8	1.094264E 00	6.000000E 01	1.380074E 01
9	1.392353E 00	6.000000E 01	1.350265E 01
10	1.725882E 00	6.000000E 01	1.316912E 01
11	2.094853E 00	6.000000E 01	1.280015E 01
12	2.499264E 00	6.000000E 01	1.239574E 01
13	2.903676E 00	6.000000E 01	1.199132E 01
14	3.308088E 00	6.000000E 01	1.158691E 01
15	3.712500E 00	6.000000E 01	1.118250E 01
16	4.116911E 00	6.000000E 01	1.077809E 01
17	4.521323E 00	6.000000E 01	1.037368E 01
18	4.925735E 00	6.000000E 01	9.969265E 00
19	5.330147E 00	6.000000E 01	9.564853E 00
20	5.734559E 00	6.000000E 01	9.160441E 00
21	6.138970E 00	6.000000E 01	8.756030E 00
22	6.543382E 00	6.000000E 01	8.351618E 00
23	6.947794E 00	6.000000E 01	7.947206E 00
24	7.352206E 00	6.000000E 01	7.542794E 00
25	7.756618E 00	6.000000E 01	7.138382E 00
26	8.161029E 00	6.000000E 01	6.733971E 00
27	8.565441E 00	6.000000E 01	6.329559E 00
28	8.969853E 00	6.000000E 01	5.925147E 00
29	9.374265E 00	6.000000E 01	5.520735E 00
30	9.778677E 00	6.000000E 01	5.116323E 00
31	1.018309E 01	6.000000E 01	4.711912E 00
32	1.056978E 01	6.000000E 01	4.325221E 00
33	1.093875E 01	6.000000E 01	3.956250E 00
34	1.129000E 01	6.000000E 01	3.605000E 00

35	1.162353E 01	6.000000E 01	3.271471E 00
36	1.193934E 01	6.000000E 01	2.955662E 00
37	1.223743E 01	6.000000E 01	2.657574E 00
38	1.251779E 01	6.000000E 01	2.377206E 00
39	1.278044E 01	6.000000E 01	2.114559E 00
40	1.302537E 01	6.000000E 01	1.869632E 00
41	1.325257E 01	6.000000E 01	1.642426E 00
42	1.346206E 01	6.000000E 01	1.432941E 00
43	1.365382E 01	6.000000E 01	1.241176E 00
44	1.382787E 01	6.000000E 01	1.067132E 00
45	1.398419E 01	6.000000E 01	9.108089E-01
46	1.412279E 01	6.000000E 01	7.722059E-01
47	1.424368E 01	6.000000E 01	6.513236E-01
48	1.434684E 01	6.000000E 01	5.481619E-01
49	1.443228E 01	6.000000E 01	4.627206E-01
50	1.450000E 01	6.000000E 01	3.950001E-01
51	1.455000E 01	6.000000E 01	3.450000E-01

SEGMENT 2

PHI(DEGREES) = 90.000001
SIN(PHI) = 1.000000
COS(PHI) = 0.

POINT	S	R	Y
1	0.	5.999910E 01	3.450000E-01
2	4.928568E-02	5.999910E 01	2.957143E-01
3	9.857140E-02	5.999910E 01	2.464286E-01
4	1.478571E-01	5.999910E 01	1.971429E-01
5	1.971428E-01	5.999910E 01	1.478572E-01
6	2.464285E-01	5.999910E 01	9.857145E-02
7	2.957143E-01	5.999910E 01	4.928574E-02
8	3.450000E-01	5.999910E 01	2.235174E-08
9	3.942857E-01	5.999910E 01	-4.928569E-02
10	4.435714E-01	5.999910E 01	-9.857141E-02
11	4.928571E-01	5.999910E 01	-1.478571E-01
12	5.421428E-01	5.999910E 01	-1.971428E-01
13	5.914286E-01	5.999910E 01	-2.464286E-01
14	6.407143E-01	5.999910E 01	-2.957143E-01
15	6.900000E-01	5.999910E 01	-3.450000E-01

SEGMENT 3

PHI(DEGREES) = 90.000001
SIN(PHI) = 1.000000
COS(PHI) = 0.

POINT	S	R	Y
1	0.	5.998250E 01	-3.450000E-01
2	5.000047E-02	5.998250E 01	-3.950005E-01
3	1.261229E-01	5.998250E 01	-4.711229E-01
4	2.283678E-01	5.998250E 01	-5.733678E-01
5	3.567352E-01	5.998250E 01	-7.017352E-01
6	5.112249E-01	5.998250E 01	-8.562249E-01
7	6.918372E-01	5.998250E 01	-1.036837E 00
8	8.985719E-01	5.998250E 01	-1.243572E 00
9	1.131429E 00	5.998250E 01	-1.476429E 00
10	1.390409E 00	5.998250E 01	-1.735409E 00
11	1.675511E 00	5.998250E 01	-2.020511E 00
12	1.986735E 00	5.998250E 01	-2.331735E 00
13	2.324082E 00	5.998250E 01	-2.669082E 00
14	2.687551E 00	5.998250E 01	-3.032551E 00
15	3.077143E 00	5.998250E 01	-3.422143E 00
16	3.492858E 00	5.998250E 01	-3.837858E 00
17	3.934694E 00	5.998250E 01	-4.279694E 00
18	4.402653E 00	5.998250E 01	-4.747653E 00
19	4.896735E 00	5.998250E 01	-5.241735E 00
20	5.416939E 00	5.998250E 01	-5.761939E 00
21	5.963266E 00	5.998250E 01	-6.308266E 00
22	6.535715E 00	5.998250E 01	-6.880715E 00
23	7.108164E 00	5.998250E 01	-7.453164E 00
24	7.680613E 00	5.998250E 01	-8.025612E 00
25	8.253062E 00	5.998250E 01	-8.598061E 00
26	8.825511E 00	5.998250E 01	-9.170510E 00
27	9.397959E 00	5.998250E 01	-9.742959E 00
28	9.970408E 00	5.998250E 01	-1.031541E 01
29	1.054286E 01	5.998250E 01	-1.088786E 01
30	1.111531E 01	5.998250E 01	-1.146031E 01
31	1.168776E 01	5.998250E 01	-1.203276E 01
32	1.226020E 01	5.998250E 01	-1.260520E 01
33	1.283265E 01	5.998250E 01	-1.317765E 01
34	1.340510E 01	5.998250E 01	-1.375010E 01
35	1.397755E 01	5.998250E 01	-1.432255E 01
36	1.455000E 01	5.998250E 01	-1.489500E 01
37	1.512245E 01	5.998250E 01	-1.546745E 01
38	1.569490E 01	5.998250E 01	-1.603990E 01

39	1.626735E 01	5.998250E 01	-1.661235E 01
40	1.683980E 01	5.998250E 01	-1.718480E 01
41	1.741224E 01	5.998250E 01	-1.775724E 01
42	1.798469E 01	5.998250E 01	-1.832969E 01
43	1.855714E 01	5.998250E 01	-1.890214E 01
44	1.912959E 01	5.998250E 01	-1.947459E 01
45	1.970204E 01	5.998250E 01	-2.004704E 01
46	2.027449E 01	5.998250E 01	-2.061949E 01
47	2.084694E 01	5.998250E 01	-2.119194E 01
48	2.141939E 01	5.998250E 01	-2.176439E 01
49	2.199184E 01	5.998250E 01	-2.233684E 01
50	2.256429E 01	5.998250E 01	-2.290929E 01
51	2.313673E 01	5.998250E 01	-2.348173E 01
52	2.368306E 01	5.998250E 01	-2.402806E 01
53	2.420327E 01	5.998250E 01	-2.454827E 01
54	2.469735E 01	5.998250E 01	-2.504235E 01
55	2.516531E 01	5.998250E 01	-2.551031E 01
56	2.560714E 01	5.998250E 01	-2.595214E 01
57	2.602286E 01	5.998250E 01	-2.636786E 01
58	2.641245E 01	5.998250E 01	-2.675745E 01
59	2.677592E 01	5.998250E 01	-2.712092E 01
60	2.711327E 01	5.998250E 01	-2.745826E 01
61	2.742449E 01	5.998250E 01	-2.776949E 01
62	2.770959E 01	5.998250E 01	-2.805459E 01
63	2.796857E 01	5.998250E 01	-2.831357E 01
64	2.820143E 01	5.998250E 01	-2.854643E 01
65	2.840816E 01	5.998250E 01	-2.875316E 01
66	2.858878E 01	5.998250E 01	-2.893377E 01
67	2.874326E 01	5.998250E 01	-2.908826E 01
68	2.887163E 01	5.998250E 01	-2.921663E 01
69	2.897388E 01	5.998250E 01	-2.931888E 01
70	2.905000E 01	5.998250E 01	-2.939500E 01
71	2.910000E 01	5.998250E 01	-2.944500E 01

FINITE DIFFERENCE COEFFICIENTS
SEGMENT NUMBER 1

POINT	FDC
1	2.0000132E 01
2	1.1703959E 01
3	8.2725061E 00
4	6.3969898E 00
5	5.2147240E 00

6	4.4012945E 00
7	3.8073909E 00
8	3.3547114E 00
9	2.9982363E 00
10	2.7102431E 00
11	2.4727273E 00
12	2.4727273E 00
13	2.4727273E 00
14	2.4727273E 00
15	2.4727273E 00
16	2.4727271E 00
17	2.4727271E 00
18	2.4727271E 00
19	2.4727271E 00
20	2.4727271E 00
21	2.4727271E 00
22	2.4727271E 00
23	2.4727271E 00
24	2.4727271E 00
25	2.4727271E 00
26	2.4727271E 00
27	2.4727271E 00
28	2.4727271E 00
29	2.4727271E 00
30	2.4727271E 00
31	2.5860435E 00
32	2.7102428E 00
33	2.8469756E 00
34	2.9982358E 00
35	3.1664731E 00
36	3.3547119E 00
37	3.5667442E 00
38	3.8073912E 00
39	4.0828583E 00
40	4.4012946E 00
41	4.7736048E 00
42	5.2147237E 00
43	5.7456731E 00
44	6.3969887E 00
45	7.2148525E 00
46	8.2725034E 00
47	9.6935207E 00

48	1.1703951E 01
49	1.4766570E 01
50	1.9999971E 01

SEGMENT NUMBER 2

POINT	FDC
1	2.0289867E 01
2	2.0289855E 01
3	2.0289854E 01
4	2.0289854E 01
5	2.0289854E 01
6	2.0289854E 01
7	2.0289854E 01
8	2.0289854E 01
9	2.0289854E 01
10	2.0289854E 01
11	2.0289854E 01
12	2.0289854E 01
13	2.0289854E 01
14	2.0289854E 01

SEGMENT NUMBER 3

POINT	FDC
1	1.9999813E 01
2	1.3136729E 01
3	9.7804391E 00
4	7.7901433E 00
5	6.4729195E 00
6	5.5367232E 00
7	4.8371176E 00
8	4.2944786E 00
9	3.8613082E 00
10	3.5075161E 00
11	3.2131149E 00
12	2.9643074E 00
13	2.7512633E 00
14	2.5667889E 00
15	2.4054982E 00
16	2.2632795E 00
17	2.1369386E 00
18	2.0239571E 00
19	1.9223225E 00
20	1.8304072E 00
21	1.7468806E 00

22	1.7468806E 00
23	1.7468806E 00
24	1.7468806E 00
25	1.7468806E 00
26	1.7468806E 00
27	1.7468806E 00
28	1.7468806E 00
29	1.7468806E 00
30	1.7468806E 00
31	1.7468806E 00
32	1.7468806E 00
33	1.7468806E 00
34	1.7468806E 00
35	1.7468806E 00
36	1.7468806E 00
37	1.7468806E 00
38	1.7468806E 00
39	1.7468806E 00
40	1.7468806E 00
41	1.7468806E 00
42	1.7468806E 00
43	1.7468806E 00
44	1.7468806E 00
45	1.7468806E 00
46	1.7468806E 00
47	1.7468806E 00
48	1.7468806E 00
49	1.7468806E 00
50	1.7468806E 00
51	1.8304068E 00
52	1.9223225E 00
53	2.0239576E 00
54	2.1369386E 00
55	2.2632802E 00
56	2.4054984E 00
57	2.5667883E 00
58	2.7512635E 00
59	2.9643065E 00
60	3.2131150E 00
61	3.5075179E 00
62	3.8613086E 00
63	4.2944769E 00

64	4.8371183E 00
65	5.5367206E 00
66	6.4729211E 00
67	7.7901528E 00
68	9.7804204E 00
69	1.3136757E 01
70	1.9999924E 01

STIFFNESSES

SEGMENT 1

POINT	E	H	MU	D	K
1	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
2	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
3	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
4	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
5	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
6	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
7	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
8	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
9	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
10	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
11	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
12	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
13	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
14	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
15	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
16	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
17	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
18	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
19	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
20	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
21	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
22	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
23	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
24	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
25	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
26	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
27	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
28	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
29	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
30	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01

31	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
32	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
33	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
34	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
35	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
36	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
37	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
38	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
39	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
40	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
41	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
42	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
43	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
44	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
45	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
46	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
47	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
48	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
49	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
50	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01
51	2.700000E 07	1.700000E-02	3.000000E-01	5.043956E 05	1.214753E 01

SEGMENT 2

POINT	E	H	MU	D	K
1	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
2	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
3	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
4	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
5	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
6	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
7	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
8	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
9	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
10	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
11	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
12	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
13	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
14	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02
15	2.700000E 07	3.500000E-02	3.000000E-01	1.038462E 06	1.060096E 02

SEGMENT 3

POINT	E	H	MU	D	K

1	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
2	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
3	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
4	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
5	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
6	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
7	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
8	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
9	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
10	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
11	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
12	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
13	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
14	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
15	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
16	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
17	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
18	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
19	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
20	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
21	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
22	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
23	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
24	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
25	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
26	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
27	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
28	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
29	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
30	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
31	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
32	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
33	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
34	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
35	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
36	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
37	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
38	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
39	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
40	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
41	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01
42	2.700000E 07	1.800000E-02	3.000000E-01	5.340659E 05	1.441978E 01

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 43      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 44      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 45      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 46      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 47      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 48      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 49      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 50      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 51      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 52      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 53      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 54      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 55      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 56      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 57      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 58      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 59      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 60      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 61      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 62      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 63      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 64      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 65      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 66      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 67      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 68      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 69      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 70      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
 71      2.700000E 07    1.800000E-02    3.000000E-01    5.340659E 05    1.441978E 01
UNDRFLOW AT 31534 IN MQ
UNDRFLOW AT 31535 IN MQ
UNDRFLOW AT 31534 IN MQ
UNDRFLOW AT 31534 IN MQ
UNDRFLOW AT 31534 IN MQ

SCALE FACTORS

  HARMONIC =  0
    1.0000000E 00   1.0000000E 00   1.0000000E 00   1.0000000E 00
    4.9999670E-02   4.9999670E-02   1.5686275E-02   3.8565596E-03
    4.9999670E-02   4.9999670E-02   4.9999670E-02   1.0000000E 00

  HARMONIC =  1
```

```
   1.0000000E 00  1.0000000E 00  1.0000000E 00  1.0000000E 00
   1.5686058E-02  4.9999670E-02  1.5621348E-02  3.8565244E-03
   4.9999670E-02  4.9999670E-02  4.9999670E-02  1.0000000E 00

HARMONIC =  2
   1.0000000E 00  1.0000000E 00  1.0000000E 00  1.0000000E 00
   3.9215551E-03  4.9999670E-02  7.8106737E-03  3.8564191E-03
   4.9999670E-02  4.9999670E-02  4.9999670E-02  1.0000000E 00

AFTER  1 COMPLETE ITERATIONS

M     I1     BETA(1)        I2     BETA(2)        I3     BETA(3)        I4     BETA(4)        I5     BETA(5)
0     39     3.270832E-03   75     3.107145E-03   75     3.032456E-03   74     2.935353E-03   40     2.861996E-03
1     52     6.793586E-01   53     6.763631E-01   54     6.734608E-01   55     6.706211E-01   56     6.678201E-01
2     73     8.658303E-03   72     8.354937E-03   74     8.205051E-03   75     7.264773E-03   71     7.136935E-03

0TH LOAD INCREMENT CONVERGED

M     I1     BETA(1)        I2     BETA(2)        I3     BETA(3)        I4     BETA(4)        I5     BETA(5)
0     73     8.735769E-03   72     8.437579E-03   74     8.283996E-03   75     7.347954E-03   71     7.228366E-03
1    137     2.003610E-03  136     1.877247E-03   73     1.664100E-03   74     1.650411E-03   72     1.476881E-03
2     73     8.658303E-03   72     8.354937E-03   74     8.205051E-03   75     7.264773E-03   71     7.136935E-03
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COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
1	1	2	1.70000E-02		6.00000E 01	0.	4.99997E-02	0.
	0.	-0.	2.29389E-01	0.	-0.	0.	2.29389E-01	-0.
	-0.	4.30311E 02	1.90779E 03	0.	4.30311E 02	0.	1.36183E-04	5.14042E-05
	0.							
	2.53152E 04	2.53096E 04	1.12224E 05	1.12222E 05	-0.	-0.	1.01952E 05	1.01951E 05
1	1	2	1.70000E-02		6.00000E 01	0.	4.99997E-02	9.00000E 01
	3.11707E-03	0.	2.29049E-01	-0.	5.80404E-05	1.16415E-10	2.29049E-01	0.
	-0.	5.18488E 02	1.90774E 03	-0.	5.18488E 02	-0.	2.72255E-04	8.18203E-05
	-8.50132E-14							
	3.05050E 04	3.04936E 04	1.12222E 05	1.12218E 05	-1.76498E-09	1.76498E-09	1.00504E 05	1.00503E 05
1	1	2	1.70000E-02		6.00000E 01	0.	4.99997E-02	1.80000E 02
	2.84515E-10	-0.	2.28658E-01	0.	5.37543E-12	1.03998E-17	2.28658E-01	-0.
	0.	6.07100E 02	1.90755E 03	0.	6.07100E 02	0.	4.17102E-04	1.14293E-04
	-7.87719E-21							
	3.57204E 04	3.57031E 04	1.12211E 05	1.12206E 05	-1.63540E-16	1.63540E-16	9.92927E 04	9.92917E 04
3	1	2	1.70000E-02		6.00000E 01	1.35441E-01	1.20882E-01	0.
	0.	-4.19089E-05	2.29389E-01	1.48152E-06	-0.	0.	2.29389E-01	-4.19089E-05
	-0.	4.30311E 02	1.90779E 03	-6.32139E-04	4.30311E 02	-6.32139E-04	1.36651E-04	5.15450E-05
	-0.							
	2.53152E 04	2.53096E 04	1.12224E 05	1.12222E 05	-0.	-0.	1.01952E 05	1.01951E 05
3	1	2	1.70000E-02		6.00000E 01	1.35441E-01	1.20882E-01	9.00000E 01
	3.11704E-03	-1.58852E-05	2.29048E-01	3.03766E-06	5.80418E-05	-4.32761E-07	2.29048E-01	-1.58852E-05
	2.77141E-04	5.18488E 02	1.90774E 03	-1.56596E-03	5.18488E 02	-1.56596E-03	2.72872E-04	8.20054E-05
	1.66427E-07							
	3.05050E 04	3.04936E 04	1.12222E 05	1.12218E 05	1.97577E-02	1.28472E-02	1.00503E 05	1.00503E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
3	1	2	1.70000E-02		6.00000E 01	1.35441E-01	1.20882E-01	1.80000E 02
	2.84513E-10	1.02794E-05	2.28658E-01	4.69353E-06	5.37557E-12	-3.96784E-14	2.28658E-01	1.02794E-05
	5.49928E-11	6.07100E 02	1.90754E 03	-2.83769E-03	6.07100E 02	-2.83769E-03	4.17840E-04	1.14515E-04
	1.64898E-14							
	3.57204E 04	3.57031E 04	1.12211E 05	1.12206E 05	3.57722E-09	2.89252E-09	9.92926E 04	9.92916E 04
5	1	2	1.70000E-02		6.00000E 01	4.12647E-01	1.91765E-01	0.
	0.	-1.27683E-04	2.29388E-01	4.55956E-06	-0.	0.	2.29388E-01	-1.27683E-04
	-0.	4.30311E 02	1.90778E 03	-1.94533E-03	4.30311E 02	-1.94533E-03	1.40552E-04	5.27172E-05
	-0.							
	2.53153E 04	2.53095E 04	1.12224E 05	1.12221E 05	-0.	-0.	1.01951E 05	1.01951E 05
5	1	2	1.70000E-02		6.00000E 01	4.12647E-01	1.91765E-01	9.00000E 01
	3.11680E-03	-4.83963E-05	2.29047E-01	9.31471E-06	5.80528E-05	-1.31837E-06	2.29047E-01	-4.83963E-05
	8.56326E-04	5.18488E 02	1.90773E 03	-4.80187E-03	5.18488E 02	-4.80187E-03	2.78002E-04	8.35446E-05
	5.08911E-07							
	3.05051E 04	3.04935E 04	1.12221E 05	1.12217E 05	6.09378E-02	3.98065E-02	1.00503E 05	1.00502E 05
5	1	2	1.70000E-02		6.00000E 01	4.12647E-01	1.91765E-01	1.80000E 02
	2.84491E-10	3.13198E-05	2.28655E-01	1.43714E-05	5.37666E-12	-1.20877E-13	2.28655E-01	3.13198E-05
	1.68729E-10	6.07100E 02	1.90753E 03	-8.68893E-03	6.07100E 02	-8.68893E-03	4.23977E-04	1.16353E-04
	5.03756E-14							
	3.57206E 04	3.57030E 04	1.12210E 05	1.12205E 05	1.09711E-08	8.87939E-09	9.92915E 04	9.92906E 04
7	1	2	1.70000E-02		6.00000E 01	8.31617E-01	2.62647E-01	0.
	0.	-2.57317E-04	2.29385E-01	9.50179E-06	-0.	0.	2.29385E-01	-2.57317E-04
	-0.	4.30311E 02	1.90775E 03	-4.05374E-03	4.30311E 02	-4.05374E-03	1.54175E-04	5.68105E-05
	-0.							
	2.53156E 04	2.53092E 04	1.12222E 05	1.12220E 05	-0.	-0.	1.01949E 05	1.01949E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
7	1	2	1.70000E-02		6.00000E 01	8.31617E-01	2.62647E-01	9.00000E 01
	3.11597E-03	-9.75261E-05	2.29041E-01	1.91829E-05	5.80909E-05	-2.65669E-06	2.29041E-01	-9.75261E-05
	1.80748E-03	5.18488E 02	1.90768E 03	-9.88905E-03	5.18488E 02	-9.88905E-03	2.95863E-04	8.89034E-05
	1.03827E-06							
	3.05054E 04	3.04931E 04	1.12218E 05	1.12215E 05	1.27878E-01	8.47663E-02	1.00500E 05	1.00500E 05
7	1	2	1.70000E-02		6.00000E 01	8.31617E-01	2.62647E-01	1.80000E 02
	2.84415E-10	6.31310E-05	2.28646E-01	2.94539E-05	5.38042E-12	-2.43582E-13	2.28646E-01	6.31310E-05
	3.48114E-10	6.07100E 02	1.90746E 03	-1.78079E-02	6.07100E 02	-1.78079E-02	4.45296E-04	1.22742E-04
	1.02448E-13							
	3.57210E 04	3.57025E 04	1.12206E 05	1.12201E 05	2.26042E-08	1.83503E-08	9.92880E 04	9.92870E 04
9	1	2	1.70000E-02		6.00000E 01	1.39235E 00	3.33529E-01	0.
	0.	-4.30798E-04	2.29377E-01	1.71891E-05	-0.	0.	2.29377E-01	-4.30798E-04
	-0.	4.30310E 02	1.90768E 03	-7.33260E-03	4.30310E 02	-7.33260E-03	1.88252E-04	6.70495E-05
	-0.							
	2.53163E 04	2.53085E 04	1.12218E 05	1.12215E 05	-0.	-0.	1.01945E 05	1.01945E 05
9	1	2	1.70000E-02		6.00000E 01	1.39235E 00	3.33529E-01	9.00000E 01
	3.11399E-03	-1.63252E-04	2.29026E-01	3.37906E-05	5.81839E-05	-4.44728E-06	2.29026E-01	-1.63252E-04
	3.35569E-03	5.18487E 02	1.90757E 03	-1.74195E-02	5.18487E 02	-1.74195E-02	3.40202E-04	1.02207E-04
	1.78897E-06							
	3.05063E 04	3.04922E 04	1.12212E 05	1.12208E 05	2.34535E-01	1.60253E-01	1.00494E 05	1.00493E 05
9	1	2	1.70000E-02		6.00000E 01	1.39235E 00	3.33529E-01	1.80000E 02
	2.84234E-10	1.05745E-04	2.28623E-01	5.13063E-05	5.38957E-12	-4.07751E-13	2.28623E-01	1.05745E-04
	6.15270E-10	6.07099E 02	1.90731E 03	-3.10206E-02	6.07099E 02	-3.10206E-02	4.97936E-04	1.38515E-04
	1.75202E-13							
	3.57221E 04	3.57014E 04	1.12197E 05	1.12192E 05	3.98298E-08	3.25549E-08	9.92793E 04	9.92781E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
11	1	2	1.70000E-02		6.00000E 01	2.09485E 00	4.04412E-01	0.
	0.	-6.48087E-04	2.29361E-01	2.98550E-05	-0.	0.	2.29361E-01	-6.48087E-04
	-0.	4.30310E 02	1.90753E 03	-1.27338E-02	4.30310E 02	-1.27338E-02	2.61527E-04	8.90649E-05
	-0.							
	2.53178E 04	2.53069E 04	1.12209E 05	1.12206E 05	-0.	-0.	1.01936E 05	1.01936E 05
11	1	2	1.70000E-02		6.00000E 01	2.09485E 00	4.04412E-01	9.00000E 01
	3.11010E-03	-2.45517E-04	2.28995E-01	5.60085E-05	5.83746E-05	-6.68903E-06	2.28995E-01	-2.45517E-04
	6.04580E-03	5.18486E 02	1.90733E 03	-2.88730E-02	5.18486E 02	-2.88730E-02	4.34110E-04	1.30381E-04
	2.84222E-06							
	3.05082E 04	3.04902E 04	1.12198E 05	1.12193E 05	4.14643E-01	2.96627E-01	1.00480E 05	1.00480E 05
11	1	2	1.70000E-02		6.00000E 01	2.09485E 00	4.04412E-01	1.80000E 02
	2.83878E-10	1.59240E-04	2.28576E-01	8.33060E-05	5.40811E-12	-6.13277E-13	2.28576E-01	1.59240E-04
	1.02316E-09	6.07098E 02	1.90697E 03	-5.03699E-02	6.07098E 02	-5.03699E-02	-6.08224E-04	1.71564E-04
	2.74382E-13							
	3.57243E 04	3.56990E 04	1.12179E 05	1.12171E 05	6.58827E-08	5.44896E-08	9.92610E 04	9.92595E 04
13	1	2	1.70000E-02		6.00000E 01	2.90368E 00	4.04412E-01	0.
	0.	-8.98148E-04	2.29329E-01	5.14226E-05	-0.	0.	2.29329E-01	-8.98148E-04
	-0.	4.30308E 02	1.90723E 03	-2.19271E-02	4.30308E 02	-2.19271E-02	4.02131E-04	1.31305E-04
	-0.							
	2.53206E 04	2.53039E 04	1.12193E 05	1.12187E 05	-0.	-0.	1.01919E 05	1.01919E 05
13	1	2	1.70000E-02		6.00000E 01	2.90368E 00	4.04412E-01	9.00000E 01
	3.10369E-03	-3.40057E-04	2.28936E-01	9.04171E-05	5.87123E-05	-9.26677E-06	2.28936E-01	-3.40057E-04
	1.07594E-02	5.18484E 02	1.90688E 03	-4.66107E-02	5.18484E 02	-4.66107E-02	6.09975E-04	1.83143E-04
	4.28843E-06							
	3.05117E 04	3.04864E 04	1.12173E 05	1.12166E 05	7.21939E-01	5.43873E-01	1.00455E 05	1.00454E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
13	1	2	1.70000E-02		6.00000E 01	2.90368E 00	4.04412E-01	1.80000E 02
	2.83291E-10	2.21069E-04	2.28491E-01	1.30417E-04	5.44033E-12	-8.49598E-13	2.28491E-01	2.21069E-04
	1.64807E-09	6.07096E 02	1.90637E 03	-7.88586E-02	6.07096E 02	-7.88586E-02	8.11175E-04	2.32384E-04
	4.04664E-13							
	3.57283E 04	3.56947E 04	1.12144E 05	1.12134E 05	1.05347E-07	8.85442E-08	9.92274E 04	9.92252E 04
15	1	2	1.70000E-02		6.00000E 01	3.71250E 00	4.04412E-01	0.
	0.	-1.14801E-03	2.29274E-01	8.51122E-05	-0.	0.	2.29274E-01	-1.14801E-03
	-0.	4.30306E 02	1.90675E 03	-3.62840E-02	4.30306E 02	-3.62840E-02	6.30163E-04	1.99804E-04
	-0.							
	2.53252E 04	2.52990E 04	1.12166E 05	1.12157E 05	-0.	-0.	1.01892E 05	1.01891E 05
15	1	2	1.70000E-02		6.00000E 01	3.71250E 00	4.04412E-01	9.00000E 01
	3.09521E-03	-4.34303E-04	2.28844E-01	1.39733E-04	5.92036E-05	-1.18394E-05	2.28844E-01	-4.34303E-04
	1.80269E-02	5.18481E 02	1.90617E 03	-7.20326E-02	5.18481E 02	-7.20326E-02	8.86404E-04	2.66074E-04
	6.08082E-06							
	3.05173E 04	3.04805E 04	1.12133E 05	1.12122E 05	1.18665E 00	9.34158E-01	1.00415E 05	1.00414E 05
15	1	2	1.70000E-02		6.00000E 01	3.71250E 00	4.04412E-01	1.80000E 02
	2.82516E-10	2.83291E-04	2.28360E-01	1.94518E-04	5.48600E-12	-1.08545E-12	2.28360E-01	2.83291E-04
	2.51297E-09	6.07092E 02	1.90543E 03	-1.17625E-01	6.07092E 02	-1.17625E-01	1.12294E-03	3.25823E-04
	5.57519E-13							
	3.57346E 04	3.56880E 04	1.12091E 05	1.12078E 05	1.59396E-07	1.36247E-07	9.91758E 04	9.91725E 04
17	1	2	1.70000E-02		6.00000E 01	4.52132E 00	4.04412E-01	0.
	0.	-1.39755E-03	2.29185E-01	1.38175E-04	-0.	0.	2.29185E-01	-1.39755E-03
	-0.	4.30303E 02	1.90598E 03	-5.88924E-02	4.30303E 02	-5.88924E-02	9.91224E-04	3.08250E-04
	0.							
	2.53325E 04	2.52914E 04	1.12123E 05	1.12110E 05	-0.	-0.	1.01848E 05	1.01848E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
17	1	2	1.70000E-02		6.00000E 01	4.52132E 00	4.04412E-01	9.00000E 01
	3.08468E-03	-5.28095E-04	2.28703E-01	2.12087E-04	5.98862E-05	-1.44048E-05	2.28703E-01	-5.28095E-04
	2.89121E-02	5.18477E 02	1.90509E 03	-1.09330E-01	5.18477E 02	-1.09330E-01	1.30898E-03	3.92846E-04
	8.31748E-06							
	3.05258E 04	3.04715E 04	1.12072E 05	1.12056E 05	1.87339E 00	1.52803E 00	1.00354E 05	1.00352E 05
17	1	2	1.70000E-02		6.00000E 01	4.52132E 00	4.04412E-01	1.80000E 02
	2.81552E-10	3.46103E-04	2.28168E-01	2.84239E-04	5.54748E-12	-1.32064E-12	2.28168E-01	3.46103E-04
	3.70820E-09	6.07087E 02	1.90404E 03	-1.71887E-01	6.07087E 02	-1.71887E-01	1.58726E-03	4.64995E-04
	7.36923E-13							
	3.57440E 04	3.56780E 04	1.12012E 05	1.11993E 05	2.33429E-07	2.02830E-07	9.90990E 04	9.90941E 04
19	1	2	1.70000E-02		6.00000E 01	5.33015E 00	4.04412E-01	0.
	0.	-1.64660E-03	2.29042E-01	2.21736E-04	-0.	0.	2.29042E-01	-1.64660E-03
	-0.	4.30297E 02	1.90479E 03	-9.44904E-02	4.30297E 02	-9.44904E-02	1.55752E-03	4.78316E-04
	0.							
	2.53440E 04	2.52793E 04	1.12056E 05	1.12036E 05	-0.	-0.	1.01779E 05	1.01779E 05
19	1	2	1.70000E-02		6.00000E 01	5.33015E 00	4.04412E-01	9.00000E 01
	3.07212E-03	-6.21205E-04	2.28490E-01	3.19411E-04	6.08063E-05	-1.69603E-05	2.28490E-01	-6.21205E-04
	4.47397E-02	5.18470E 02	1.90346E 03	-1.64652E-01	5.18470E 02	-1.64652E-01	1.94741E-03	5.84364E-04
	1.10767E-05							
	3.05387E 04	3.04578E 04	1.11981E 05	1.11956E 05	2.86171E 00	2.40178E 00	1.00262E 05	1.00259E 05
19	1	2	1.70000E-02		6.00000E 01	5.33015E 00	4.04412E-01	1.80000E 02
	2.80403E-10	4.09776E-04	2.27889E-01	4.11800E-04	5.62735E-12	-1.55499E-12	2.27889E-01	4.09776E-04
	5.33951E-09	6.07079E 02	1.90200E 03	-2.49035E-01	6.07079E 02	-2.49035E-01	2.26926E-03	6.69433E-04
	9.43334E-13							
	3.57577E 04	3.56634E 04	1.11896E 05	1.11869E 05	3.33674E-07	2.94504E-07	9.89861E 04	9.89790E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
21	1	2	1.70000E-02		6.00000E 01	6.13897E 00	4.04412E-01	0.
	0.	-1.89488E-03	2.28812E-01	3.53018E-04	-0.	0.	2.28812E-01	-1.89488E-03
	-0.	4.30289E 02	1.90292E 03	-1.50415E-01	4.30289E 02	-1.50415E-01	2.44229E-03	7.43989E-04
	0.							
	2.53618E 04	2.52604E 04	1.11952E 05	1.11921E 05	-0.	-0.	1.01672E 05	1.01672E 05
21	1	2	1.70000E-02		6.00000E 01	6.13897E 00	4.04412E-01	9.00000E 01
	3.05754E-03	-7.13299E-04	2.28170E-01	4.79403E-04	6.20153E-05	-1.95031E-05	2.28170E-01	-7.13299E-04
	6.71379E-02	5.18459E 02	1.90101E 03	-2.47120E-01	5.18459E 02	-2.47120E-01	2.90699E-03	8.72219E-04
	1.43808E-05							
	3.05580E 04	3.04373E 04	1.11842E 05	1.11806E 05	4.24785E 00	3.65073E 00	1.00124E 05	1.00120E 05
21	1	2	1.70000E-02		6.00000E 01	6.13897E 00	4.04412E-01	1.80000E 02
	2.79069E-10	4.74696E-04	2.27485E-01	5.94729E-04	5.72795E-12	-1.78829E-12	2.27485E-01	4.74696E-04
	7.52807E-09	6.07068E 02	1.89902E 03	-3.59666E-01	6.07068E 02	-3.59666E-01	3.26461E-03	9.67835E-04
	1.17041E-12							
	3.57777E 04	3.56421E 04	1.11727E 05	1.11687E 05	4.67127E-07	4.18528E-07	9.88215E 04	9.88109E 04
23	1	2	1.70000E-02		6.00000E 01	6.94779E 00	4.04412E-01	0.
	0.	-2.14198E-03	2.28448E-01	5.58789E-04	-0.	0.	2.28448E-01	-2.14198E-03
	-0.	4.30276E 02	1.90000E 03	-2.38071E-01	4.30276E 02	-2.38071E-01	3.82244E-03	1.15836E-03
	0.							
	2.53897E 04	2.52310E 04	1.11789E 05	1.11741E 05	-0.	-0.	1.01504E 05	1.01505E 05
23	1	2	1.70000E-02		6.00000E 01	6.94779E 00	4.04412E-01	9.00000E 01
	3.04097E-03	-8.03893E-04	2.27691E-01	7.18451E-04	6.35613E-05	-2.20297E-05	2.27691E-01	-8.03893E-04
	9.80474E-02	5.18444E 02	1.89734E 03	-3.70331E-01	5.18444E 02	-3.70331E-01	4.34605E-03	1.30390E-03
	1.81263E-05							
	3.05869E 04	3.04065E 04	1.11635E 05	1.11581E 05	6.14382E 00	5.39117E 00	9.99171E 04	9.99106E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
23	1	2	1.70000E-02		6.00000E 01	6.94779E 00	4.04412E-01	1.80000E 02
	2.77553E-10	5.41397E-04	2.26903E-01	8.58323E-04	5.85045E-12	-2.02031E-12	2.26903E-01	5.41397E-04
	1.04063E-08	6.07052E 02	1.89469E 03	-5.19071E-01	6.07052E 02	-5.19071E-01	4.71297E-03	1.40210E-03
	1.39946E-12							
	3.58068E 04	3.56111E 04	1.11481E 05	1.11423E 05	6.41187E-07	5.83078E-07	9.85820E 04	9.85664E 04
25	1	2	1.70000E-02		6.00000E 01	7.75662E 00	4.04412E-01	0.
	0.	-2.38729E-03	2.27873E-01	8.80710E-04	-0.	0.	2.27873E-01	-2.38729E-03
	-0.	4.30256E 02	1.89546E 03	-3.75213E-01	4.30256E 02	-3.75213E-01	5.97394E-03	1.80423E-03
	0.							
	2.54332E 04	2.51851E 04	1.11535E 05	1.11460E 05	-0.	-0.	1.01243E 05	1.01245E 05
25	1	2	1.70000E-02		6.00000E 01	7.75662E 00	4.04412E-01	9.00000E 01
	3.02245E-03	-8.92300E-04	2.26972E-01	1.07599E-03	6.54715E-05	-2.45367E-05	2.26972E-01	-8.92300E-04
	1.39650E-01	5.18421E 02	1.89184E 03	-5.54600E-01	5.18421E 02	-5.54600E-01	6.50208E-03	1.95064E-03
	2.19565E-05							
	3.06303E 04	3.03604E 04	1.11325E 05	1.11244E 05	8.67058E 00	7.75889E 00	9.96070E 04	9.95971E 04
25	1	2	1.70000E-02		6.00000E 01	7.75662E 00	4.04412E-01	1.80000E 02
	2.75857E-10	6.10619E-04	2.26061E-01	1.23920E-03	5.99330E-12	-2.25089E-12	2.26061E-01	6.10619E-04
	1.41059E-08	6.07028E 02	1.88839E 03	-7.49371E-01	6.07028E 02	-7.49371E-01	6.81763E-03	2.03321E-03
	1.59020E-12							
	3.58490E 04	3.55660E 04	1.11124E 05	1.11039E 05	8.62775E-07	7.96746E-07	9.82342E 04	9.82112E 04
27	1	2	1.70000E-02		6.00000E 01	8.56544E 00	4.04412E-01	0.
	0.	-2.62991E-03	2.26969E-01	1.38367E-03	0.	0.	2.26969E-01	-2.62991E-03
	-0.	4.30224E 02	1.88837E 03	-5.89499E-01	4.30224E 02	-5.89499E-01	9.32704E-03	2.81067E-03
	0.							
	2.55009E 04	2.51137E 04	1.11139E 05	1.11022E 05	-0.	-0.	1.00837E 05	1.00839E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
27	1	2	1.70000E-02		6.00000E 01	8.56544E 00	4.04412E-01	9.00000E 01
	3.00201E-03	-9.77564E-04	2.25897E-01	1.61101E-03	6.77182E-05	-2.70213E-05	2.25897E-01	-9.77564E-04
	1.94145E-01	5.18387E 02	1.88360E 03	-8.30309E-01	5.18387E 02	-8.30309E-01	9.73107E-03	2.91924E-03
	2.50353E-05							
	3.06954E 04	3.02913E 04	1.10860E 05	1.10739E 05	1.19400E 01	1.09005E 01	9.91430E 04	9.91277E 04
27	1	2	1.70000E-02		6.00000E 01	8.56544E 00	4.04412E-01	1.80000E 02
	2.73984E-10	6.83355E-04	2.24846E-01	1.79043E-03	6.14951E-12	-2.47998E-12	2.24846E-01	6.83355E-04
	1.87336E-08	6.06992E 02	1.87924E 03	-1.08262E 00	6.06992E 02	-1.08262E 00	9.87413E-03	2.94984E-03
	1.66596E-12							
	3.59104E 04	3.55004E 04	1.10605E 05	1.10482E 05	1.13656E-06	1.06739E-06	9.77296E 04	9.76955E 04
29	1	2	1.70000E-02		6.00000E 01	9.37426E 00	4.04412E-01	0.
	0.	-2.86863E-03	2.25550E-01	2.16877E-03	0.	0.	2.25550E-01	-2.86863E-03
	-0.	4.30175E 02	1.87733E 03	-9.24024E-01	4.30175E 02	-9.24024E-01	1.45525E-02	4.37889E-03
	0.							
	2.56066E 04	2.50023E 04	1.10522E 05	1.10340E 05	-0.	-0.	1.00204E 05	1.00207E 05
29	1	2	1.70000E-02		6.00000E 01	9.37426E 00	4.04412E-01	9.00000E 01
	2.97970E-03	-1.05843E-03	2.24286E-01	2.41182E-03	7.01556E-05	-2.94834E-05	2.24286E-01	-1.05843E-03
	2.63221E-01	5.18335E 02	1.87126E 03	-1.24292E 00	5.18335E 02	-1.24292E 00	1.45665E-02	4.36973E-03
	2.56559E-05							
	3.07927E 04	3.01879E 04	1.10165E 05	1.09983E 05	1.60162E 01	1.49509E 01	9.84490E 04	9.84250E 04
29	1	2	1.70000E-02		6.00000E 01	9.37426E 00	4.04412E-01	1.80000E 02
	2.71937E-10	7.60881E-04	2.23090E-01	2.58904E-03	6.30209E-12	-2.70777E-12	2.23090E-01	7.60881E-04
	2.43232E-08	6.06941E 02	1.86596E 03	-1.56531E 00	6.06941E 02	-1.56531E 00	1.43120E-02	4.28090E-03
	1.49006E-12							
	3.59995E 04	3.54053E 04	1.09851E 05	1.09673E 05	1.46171E-06	1.39984E-06	9.69982E 04	9.69473E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
31	1	2	1.70000E-02		6.00000E 01	1.01831E 01	3.86691E-01	0.
	0.	-3.10193E-03	2.23327E-01	3.39357E-03	0.	0.	2.23327E-01	-3.10193E-03
	0.	4.30100E 02	1.86013E 03	-1.44594E 00	4.30100E 02	-1.44594E 00	2.26964E-02	6.82266E-03
	0.							
	2.57712E 04	2.48288E 04	1.09561E 05	1.09278E 05	0.	0.	9.92181E 04	9.92211E 04
31	1	2	1.70000E-02		6.00000E 01	1.01831E 01	3.86691E-01	9.00000E 01
	2.95556E-03	-1.13337E-03	2.21875E-01	3.61067E-03	7.24077E-05	-3.19284E-05	2.21875E-01	-1.13337E-03
	3.47009E-01	5.18259E 02	1.85279E 03	-1.86045E 00	5.18259E 02	-1.86045E 00	2.18081E-02	6.54203E-03
	2.05735E-05							
	3.09386E 04	3.00331E 04	1.09123E 05	1.08852E 05	2.08395E 01	1.99852E 01	9.74115E 04	9.73733E 04
31	1	2	1.70000E-02		6.00000E 01	1.01831E 01	3.86691E-01	1.80000E 02
	2.69718E-10	8.44707E-04	2.20550E-01	3.74681E-03	6.41673E-12	-2.93496E-12	2.20550E-01	8.44707E-04
	3.07531E-08	6.06865E 02	1.84669E 03	-2.26484E 00	6.06865E 02	-2.26484E 00	2.07556E-02	6.21375E-03
	8.29019E-13							
	3.61289E 04	3.52671E 04	1.08758E 05	1.08500E 05	1.82622E-06	1.79180E-06	9.59386E 04	9.58617E 04
33	1	2	1.70000E-02		6.00000E 01	1.09387E 01	3.51250E-01	0.
	0.	-3.31376E-03	2.20134E-01	5.14938E-03	0.	0.	2.20134E-01	-3.31376E-03
	0.	4.29992E 02	1.83548E 03	-2.19412E 00	4.29992E 02	-2.19412E 00	3.43655E-02	1.03238E-02
	0.							
	2.60071E 04	2.45802E 04	1.08184E 05	1.07755E 05	0.	0.	9.78087E 04	9.78096E 04
33	1	2	1.70000E-02		6.00000E 01	1.09387E 01	3.51250E-01	9.00000E 01
	2.93137E-03	-1.19676E-03	2.18551E-01	5.26332E-03	7.36493E-05	-3.42118E-05	2.18551E-01	-1.19676E-03
	4.35682E-01	5.18154E 02	1.82733E 03	-2.71143E 00	5.18154E 02	-2.71143E 00	3.17949E-02	9.53787E-03
	5.54225E-06							
	3.11397E 04	2.98195E 04	1.07688E 05	1.07292E 05	2.57434E 01	2.55133E 01	9.59846E 04	9.59239E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
33	1	2	1.70000E-02		6.00000E 01	1.09387E 01	3.51250E-01	1.80000E 02
	2.67489E-10	9.30020E-04	2.17159E-01	5.29486E-03	6.43445E-12	-3.14804E-12	2.17159E-01	9.30020E-04
	3.71588E-08	6.06764E 02	1.82090E 03	-3.19977E 00	6.06764E 02	-3.19977E 00	2.93813E-02	8.80142E-03
	-5.64183E-13							
	3.63020E 04	3.50820E 04	1.07295E 05	1.06929E 05	2.17410E-06	2.19753E-06	9.45249E 04	9.44103E 04
35	1	2	1.70000E-02		6.00000E 01	1.16235E 01	3.15809E-01	0.
	0.	-3.50052E-03	2.15838E-01	7.50736E-03	0.	0.	2.15838E-01	-3.50052E-03
	0.	4.29850E 02	1.80240E 03	-3.19874E 00	4.29850E 02	-3.19874E 00	5.00354E-02	1.50248E-02
	0.							
	2.63241E 04	2.42465E 04	1.06335E 05	1.05712E 05	0.	0.	9.59218E 04	9.59150E 04
35	1	2	1.70000E-02		6.00000E 01	1.16235E 01	3.15809E-01	9.00000E 01
	2.90807E-03	-1.24835E-03	2.14245E-01	7.40508E-03	7.30267E-05	-3.63058E-05	2.14245E-01	-1.24835E-03
	5.17964E-01	5.18018E 02	1.79435E 03	-3.81374E 00	5.18018E 02	-3.81374E 00	4.47437E-02	1.34224E-02
	-2.35712E-05							
	3.14006E 04	2.95427E 04	1.05828E 05	1.05271E 05	2.99791E 01	3.09578E 01	9.41413E 04	9.40467E 04
35	1	2	1.70000E-02		6.00000E 01	1.16235E 01	3.15809E-01	1.80000E 02
	2.65338E-10	1.01370E-03	2.12891E-01	7.24601E-03	6.30219E-12	-3.34390E-12	2.12891E-01	1.01370E-03
	4.26768E-08	6.06634E 02	1.78840E 03	-4.37753E 00	6.06634E 02	-4.37753E 00	4.02629E-02	1.20662E-02
	-2.89403E-12							
	3.65203E 04	3.48485E 04	1.05450E 05	1.04949E 05	2.45032E-06	2.57048E-06	9.27492E 04	9.25821E 04
37	1	2	1.70000E-02		6.00000E 01	1.22374E 01	2.80368E-01	0.
	0.	-3.66574E-03	2.10343E-01	1.05206E-02	0.	0.	2.10343E-01	-3.66574E-03
	0.	4.29668E 02	1.76014E 03	-4.48215E 00	4.29668E 02	-4.48215E 00	7.00660E-02	2.10335E-02
	-0.							
	2.67293E 04	2.38199E 04	1.03974E 05	1.03101E 05	0.	0.	9.35200E 04	9.34953E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT U	HARMONIC V	THICKNESS W	OMEGA(T)	RADIUS OMEGA(P)	S OMEGA	ARC DELTA(R)	THETA DELTA(Y)
	NBAR(P-T) M(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
37	1	2	1.70000E-02		6.00000E 01	1.22374E 01	2.80368E-01	9.00000E 01
	2.88604E-03	-1.29111E-03	2.08916E-01	1.00550E-02	6.97509E-05	-3.82396E-05	2.08916E-01	-1.29111E-03
	5.82845E-01	5.17850E 02	1.75353E 03	-5.17728E 00	5.17850E 02	-5.17728E 00	6.07805E-02	1.82333E-02
	-7.04507E-05							
	3.17236E 04	3.91999E 04	1.03527E 05	1.02770E 05	3.28224E 01	3.57477E 01	9.18697E 04	9.17251E 04
37	1	2	1.70000E-02		6.00000E 01	1.22374E 01	2.80368E-01	1.80000E 02
	2.63299E-10	1.09320E-03	2.07745E-01	9.60146E-03	5.97730E-12	-3.52439E-12	2.07745E-01	1.09320E-03
	4.65589E-08	6.06477E 02	1.74915E 03	-5.79845E 00	6.06477E 02	-5.79845E 00	5.34110E-02	1.60112E-02
	-6.31322E-12							
	3.67840E 04	3.45663E 04	1.03224E 05	1.02559E 05	2.60769E-06	2.86983E-06	9.06159E 04	9.03775E 04
39	1	2	1.70000E-02		6.00000E 01	1.27804E 01	2.44926E-01	0.
	0.	-3.81488E-03	2.03675E-01	1.41755E-02	0.	0.	2.03675E-01	-3.81488E-03
	0.	4.29450E 02	1.70891E 03	-6.03808E 00	4.29450E 02	-6.03808E 00	9.43627E-02	2.83212E-02
	-0.							
	2.72209E 04	2.33027E 04	1.01112E 05	9.99361E 04	0.	0.	9.06216E 04	9.05619E 04
39	1	2	1.70000E-02		6.00000E 01	1.27804E 01	2.44926E-01	9.00000E 01
	2.86558E-03	-1.32934E-03	2.02636E-01	1.31815E-02	6.32423E-05	-4.00397E-05	2.02636E-01	-1.32934E-03
	6.20100E-01	5.17651E 02	1.70542E 03	-6.78379E 00	5.17651E 02	-6.78379E 00	7.96975E-02	2.39085E-02
	-1.37204E-04							
	3.21047E 04	2.87955E 04	1.00815E 05	9.98226E 04	3.36280E 01	3.93250E 01	8.92065E 04	8.89904E 04
39	1	2	1.70000E-02		6.00000E 01	1.27804E 01	2.44926E-01	1.80000E 02
	2.61403E-10	1.16495E-03	2.01817E-01	1.23179E-02	5.43631E-12	-3.69093E-12	2.01817E-01	1.16495E-03
	4.81967E-08	6.06295E 02	1.70391E 03	-7.43590E 00	6.06295E 02	-7.43590E 00	6.85916E-02	2.05665E-02
	-1.08571E-11							
	3.70885E 04	3.42404E 04	1.00657E 05	9.98028E 04	2.60969E-06	3.06050E-06	8.81711E 04	8.78392E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
41	1	2	1.70000E-02		6.00000E 01	1.32526E 01	2.09485E-01	0.
	0.	-3.95429E-03	1.96026E-01	1.83587E-02	0.	0.	1.96026E-01	-3.95429E-03
	0.	4.29201E 02	1.65018E 03	-7.82165E 00	4.29201E 02	-7.82165E 00	1.21547E-01	3.64744E-02
	-0.							
	2.77706E 04	2.27237E 04	9.78266E 04	9.63121E 04	0.	0.	8.73187E 04	8.71999E 04
41	1	2	1.70000E-02		6.00000E 01	1.32526E 01	2.09485E-01	9.00000E 01
	2.84697E-03	-1.36781E-03	1.95612E-01	1.66754E-02	5.33582E-05	-4.17213E-05	1.95612E-01	-1.36781E-03
	6.22955E-01	5.17430E 02	1.65162E 03	-8.57990E 00	5.17430E 02	-8.57990E 00	1.00606E-01	3.01815E-02
	-2.22686E-04							
	3.25257E 04	2.83483E 04	9.77806E 04	9.65274E 04	3.20212E 01	4.12676E 01	8.62472E 04	8.59347E 04
41	1	2	1.70000E-02		6.00000E 01	1.32526E 01	2.09485E-01	1.80000E 02
	2.59679E-10	1.22513E-03	1.95317E-01	1.52981E-02	4.68610E-12	-3.84403E-12	1.95317E-01	1.22513E-03
	4.72846E-08	6.06094E 02	1.65426E 03	-9.23150E 00	6.06094E 02	-9.23150E 00	8.51706E-02	2.55417E-02
	-1.63930E-11							
	3.74208E 04	3.38843E 04	9.78399E 04	9.67794E 04	2.44111E-06	3.12179E-06	8.55086E 04	8.50593E 04
43	1	2	1.70000E-02		6.00000E 01	1.36538E 01	1.74044E-01	0.
	0.	-4.08866E-03	1.87799E-01	2.27255E-02	-0.	0.	1.87799E-01	-4.08866E-03
	0.	4.28935E 02	1.58704E 03	-9.74369E 00	4.28935E 02	-9.74369E 00	1.40291E-01	4.20946E-02
	-0.							
	2.81441E 04	2.23189E 04	9.42291E 04	9.24813E 04	0.	0.	8.37808E 04	8.35873E 04
43	1	2	1.70000E-02		6.00000E 01	1.36538E 01	1.74044E-01	9.00000E 01
	2.83050E-03	-1.41009E-03	1.88209E-01	2.02896E-02	4.06915E-05	-4.32778E-05	1.88209E-01	-1.41009E-03
	5.90664E-01	5.17196E 02	1.59491E 03	-1.04747E 01	5.17196E 02	-1.04747E 01	1.16755E-01	3.50266E-02
	-3.15813E-04							
	3.28472E 04	2.79993E 04	9.45457E 04	9.30913E 04	2.81883E 01	4.13016E 01	8.31400E 04	8.27252E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
43	1	2	1.70000E-02		6.00000E 01	1.36538E 01	1.74044E-01	1.80000E 02
	2.58152E-10	1.27078E-03	1.88577E-01	1.83538E-02	3.77415E-12	-3.98278E-12	1.88577E-01	1.27078E-03
	4.39470E-08	6.05884E 02	1.60277E 03	-1.10946E 01	6.05884E 02	-1.10946E 01	9.90095E-02	2.96952E-02
	-2.23899E-11							
	3.76958E 04	3.35847E 04	9.48970E 04	9.36640E 04	2.12028E-06	3.04996E-06	8.27599E 04	8.21900E 04
45	1	2	1.70000E-02		6.00000E 01	1.39842E 01	1.38603E-01	0.
	0.	-4.21514E-03	1.79716E-01	2.59956E-02	-0.	0.	1.79716E-01	-4.21514E-03
	0.	4.28675E 02	1.52502E 03	-1.16708E 01	4.28675E 02	-1.16708E 01	7.83586E-02	2.35119E-02
	-0.							
	2.68430E 04	2.35893E 04	9.01953E 04	8.92191E 04	0.	0.	8.02161E 04	8.00742E 04
45	1	2	1.70000E-02		6.00000E 01	1.39842E 01	1.38603E-01	9.00000E 01
	2.81642E-03	-1.45491E-03	1.81017E-01	2.31041E-02	2.71544E-05	-4.46589E-05	1.81017E-01	-1.45491E-03
	5.30596E-01	5.16968E 02	1.53982E 03	-1.23423E 01	5.16968E 02	-1.23423E 01	7.30463E-02	2.19146E-02
	-3.73851E-04							
	3.19264E 04	2.88934E 04	9.10328E 04	9.01228E 04	2.34499E 01	3.89732E 01	7.99995E 04	7.97057E 04
45	1	2	1.70000E-02		6.00000E 01	1.39842E 01	1.38603E-01	1.80000E 02
	2.56848E-10	1.30216E-03	1.82091E-01	2.08077E-02	2.81714E-12	-4.10375E-12	1.82091E-01	1.30216E-03
	3.88126E-08	6.05682E 02	1.55320E 03	-1.29066E 01	6.05682E 02	-1.29066E 01	6.78345E-02	2.03447E-02
	-2.64637E-11							
	3.70367E 04	3.42200E 04	9.17869E 04	9.09421E 04	1.73368E-06	2.83252E-06	7.99817E 04	7.95578E 04
47	1	2	1.70000E-02		6.00000E 01	1.42437E 01	1.03162E-01	0.
	0.	-4.31265E-03	1.73055E-01	2.42966E-02	-0.	0.	1.73055E-01	-4.31265E-03
	0.	4.28461E 02	1.47391E 03	-1.34315E 01	4.28461E 02	-1.34315E 01	-3.18000E-01	-9.53980E-02
	-0.							
	1.86015E 04	3.18056E 04	8.47200E 04	8.86811E 04	0.	0.	7.71205E 04	7.78164E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
47	1	2	1.70000E-02		6.00000E 01	1.42437E 01	1.03162E-01	9.00000E 01
	2.80502E-03	-1.48809E-03	1.75073E-01	2.17841E-02	1.61989E-05	-4.57570E-05	1.75073E-01	-1.48809E-03
	4.58627E-01	5.16780E 02	1.49430E 03	-1.40285E 01	5.16780E 02	-1.40285E 01	-2.73239E-01	-8.19707E-02
	-3.27279E-04							
	2.47261E 04	3.60716E 04	8.61981E 04	8.96017E 04	2.01833E 01	3.37728E 01	7.68775E 04	7.80869E 04
47	1	2	1.70000E-02		6.00000E 01	1.42437E 01	1.03162E-01	1.80000E 02
	2.55794E-10	1.32897E-03	1.76721E-01	1.97683E-02	2.03648E-12	-4.19871E-12	1.76721E-01	1.32897E-03
	3.30209E-08	6.05514E 02	1.51215E 03	-1.45272E 01	6.05514E 02	-1.45272E 01	-2.37894E-01	-7.13724E-02
	-2.34805E-11							
	3.06795E 04	4.05574E 04	8.74685E 04	9.04321E 04	1.45492E-06	2.42989E-06	7.68667E 04	7.84549E 04
49	1	2	1.70000E-02		6.00000E 01	1.44323E 01	6.77205E-02	0.
	0.	-4.35296E-03	1.69436E-01	1.19300E-02	-0.	0.	1.69436E-01	-4.35296E-03
	0.	4.28344E 02	1.44613E 03	-1.48385E 01	4.28344E 02	-1.48385E 01	-1.43181E 00	-4.29541E-01
	-0.							
	-4.52937E 03	5.49228E 04	7.61487E 04	9.39843E 04	0.	0.	7.85114E 04	8.17783E 04
49	1	2	1.70000E-02		6.00000E 01	1.44323E 01	6.77205E-02	9.00000E 01
	2.79655E-03	-1.48745E-03	1.71849E-01	1.02854E-02	1.01427E-05	-4.64844E-05	1.71849E-01	-1.48745E-03
	3.93931E-01	5.16678E 02	1.46960E 03	-1.53676E 01	5.16678E 02	-1.53676E 01	-1.37814E 00	-4.13442E-01
	-2.17043E-04							
	1.78038E 03	5.90048E 04	7.78634E 04	9.50306E 04	1.86663E 01	2.76785E 01	7.69885E 04	8.30970E 04
49	1	2	1.70000E-02		6.00000E 01	1.44323E 01	6.77205E-02	1.80000E 02
	2.55012E-10	1.36901E-03	1.73812E-01	8.95880E-03	1.60086E-12	-4.25872E-12	1.73812E-01	1.36901E-03
	2.79243E-08	6.05423E 02	1.48994E 03	-1.58073E 01	6.05423E 02	-1.58073E 01	-1.33739E 00	-4.01219E-01
	-1.57205E-11							
	7.84730E 03	6.33789E 04	7.93139E 04	9.59735E 04	1.31623E-06	1.96898E-06	7.56960E 04	8.45287E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
51	1	2	1.70000E-02		6.00000E 01	1.45500E 01	0.	0.
	0.	-4.35779E-03	1.69171E-01	-9.41505E-03	-0.	0.	1.69171E-01	-4.35779E-03
	0.	4.28335E 02	1.44406E 03	-1.57466E 01	4.28335E 02	-1.57466E 01	-3.11794E 00	-9.35381E-01
	-0.							
	-3.95361E 04	8.99284E 04	6.55248E 04	1.04364E 05	0.	0.	9.19086E 04	9.79474E 04
51	1	2	1.70000E-02		6.00000E 01	1.45500E 01	0.	9.00000E 01
	2.79120E-03	-1.47122E-03	1.71767E-01	-1.10487E-02	7.23601E-06	-4.68729E-05	1.71767E-01	-1.47122E-03
	3.49640E-01	5.16676E 02	1.46897E 03	-1.62288E 01	5.16676E 02	-1.62288E 01	-3.19568E 00	-9.58702E-01
	-2.25454E-04							
	-3.59535E 04	9.67389E 04	6.65063E 04	1.06314E 05	1.58864E 01	2.52478E 01	9.00382E 04	1.01865E 05
51	1	2	1.70000E-02		6.00000E 01	1.45500E 01	0.	1.80000E 02
	2.54519E-10	1.40636E-03	1.73885E-01	-1.25041E-02	1.38012E-12	-4.28632E-12	1.73885E-01	1.40636E-03
	2.44578E-08	6.05426E 02	1.49054E 03	-1.66282E 01	6.05426E 02	-1.66282E 01	-3.29078E 00	-9.87235E-01
	-1.82972E-11							
	-3.27073E 04	1.03934E 05	6.71826E 04	1.08175E 05	1.05882E-06	1.81857E-06	8.82079E 04	1.06118E 05

MAXIMUM STRESS = 1.06118E 05 THETA = 1.80000E 02 POINT 51

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
1	2	2	3.50000E-02		5.99991E 01	0.	4.92857E-02	0.
	0.	-4.27305E-03	1.69171E-01	-9.41505E-03	-0.	-0.	1.69171E-01	-4.27305E-03
	0.	4.28341E 02	2.83704E 03	-8.84091E 00	4.28341E 02	-8.84091E 00	1.76965E 00	5.30895E-01
	-0.							
	2.09060E 04	3.57063E 03	8.36586E 04	7.84580E 04	0.	0.	7.54112E 04	7.67350E 04
1	2	2	3.50000E-02		5.99991E 01	0.	4.92857E-02	9.00000E 01
	2.79113E-03	-1.37178E-03	1.71767E-01	-1.10487E-02	7.23503E-06	-4.75965E-05	1.71767E-01	-1.37178E-03
	3.76883E-01	5.16684E 02	2.86028E 03	-9.34179E 00	5.16684E 02	-9.34179E 00	2.48416E 00	7.45262E-01
	-1.96873E-03							
	2.69297E 04	2.59506E 03	8.53725E 04	7.80719E 04	1.12533E 00	2.04108E 01	7.55950E 04	7.68073E 04
1	2	2	3.50000E-02		5.99991E 01	0.	4.92857E-02	1.80000E 02
	2.54507E-10	1.51890E-03	1.73885E-01	-1.25041E-02	1.37993E-12	-4.33685E-12	1.73885E-01	1.51890E-03
	2.85242E-08	6.05435E 02	2.87649E 03	-9.77700E 00	6.05435E 02	-9.77700E 00	3.18246E 00	9.54714E-01
	-1.59763E-10							
	3.28857E 04	1.71058E 03	8.68617E 04	7.75094E 04	3.24660E-08	1.59749E-06	7.59600E 04	7.66684E 04
3	2	2	3.50000E-02		5.99991E 01	9.85714E-02	4.92857E-02	0.
	0.	-4.32119E-03	1.70038E-01	-8.32366E-03	-0.	-0.	1.70038E-01	-4.32119E-03
	0.	4.28368E 02	2.85064E 03	-7.29986E 00	4.28368E 02	-7.29986E 00	6.02570E-01	1.80766E-01
	-0.							
	1.51904E 04	9.28771E 03	8.23322E 04	8.05614E 04	0.	0.	7.58860E 04	7.63425E 04
3	2	2	3.50000E-02		5.99991E 01	9.85714E-02	4.92857E-02	9.00000E 01
	2.78649E-03	-1.41272E-03	1.72766E-01	-9.38480E-03	5.10139E-06	-4.77814E-05	1.72766E-01	-1.41272E-03
	3.42724E-01	5.16715E 02	2.87603E 03	-7.76085E 00	5.16715E 02	-7.76085E 00	1.12476E 00	3.37440E-01
	-1.27277E-03							
	2.02723E 04	9.25429E 03	8.38249E 04	8.05194E 04	3.55815E 00	1.60261E 01	7.57513E 04	7.63143E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
3	2	2	3.50000E-02		5.99991E 01	9.85714E-02	4.92857E-02	1.80000E 02
	2.54084E-10	1.48543E-03	1.74999E-01	-1.02869E-02	1.21035E-12	-4.35340E-12	1.74999E-01	1.48543E-03
	2.64779E-08	6.05471E 02	2.89413E 03	-8.16809E 00	6.05471E 02	-8.16809E 00	1.62300E 00	4.86878E-01
	-9.83204E-11							
	2.52485E 04	9.34980E 03	8.50741E 04	8.03047E 04	2.74943E-07	1.23808E-06	7.56776E 04	7.60620E 04
5	2	2	3.50000E-02		5.99991E 01	1.97143E-01	4.92857E-02	0.
	0.	-4.36924E-03	1.70849E-01	-8.23264E-03	-0.	-0.	1.70849E-01	-4.36924E-03
	0.	4.28392E 02	2.86334E 03	-5.73741E 00	4.28392E 02	-5.73741E 00	-3.87062E-01	-1.16126E-01
	-0.							
	1.03440E 04	1.41356E 04	8.12408E 04	8.23784E 04	0.	0.	7.65945E 04	7.62990E 04
5	2	2	3.50000E-02		5.99991E 01	1.97143E-01	4.92857E-02	9.00000E 01
	2.78183E-03	-1.45310E-03	1.73660E-01	-8.88331E-03	3.75383E-06	-4.79692E-05	1.73660E-01	-1.45310E-03
	3.05837E-01	5.16744E 02	2.89011E 03	-6.15566E 00	5.16744E 02	-6.15566E 00	-2.31154E-02	-6.92112E-03
	-7.79765E-04							
	1.46509E 04	1.48773E 04	8.25407E 04	8.26085E 04	4.92039E 00	1.25589E 01	7.62779E 04	7.62660E 04
5	2	2	3.50000E-02		5.99991E 01	1.97143E-01	4.92857E-02	1.80000E 02
	2.53659E-10	1.45307E-03	1.75962E-01	-9.39819E-03	1.10937E-12	-4.36979E-12	1.75962E-01	1.45307E-03
	2.42240E-08	6.05502E 02	2.90937E 03	-6.53246E 00	6.05502E 02	-6.53246E 00	3.15265E-01	9.45600E-02
	-5.58948E-11							
	1.88442E 04	1.57559E 04	8.35881E 04	8.26618E 04	4.18344E-07	9.65885E-07	7.59403E 04	7.60185E 04
7	2	2	3.50000E-02		5.99991E 01	2.95714E-01	4.92857E-02	0.
	0.	-4.41798E-03	1.71693E-01	-8.99452E-03	-0.	-0.	1.71693E-01	-4.41798E-03
	0.	4.28418E 02	2.87657E 03	-4.15383E 00	4.28418E 02	-4.15383E 00	-1.23620E 00	-3.70869E-01
	-0.							
	6.18567E 03	1.82954E 04	8.03711E 04	8.40041E 04	0.	0.	7.74637E 04	7.65148E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
7	2	2	3.50000E-02		5.99991E 01	2.95714E-01	4.92857E-02	9.00000E 01
	2.77715E-03	-1.49391E-03	1.74554E-01	-9.37235E-03	2.94617E-06	-4.81599E-05	1.74554E-01	-1.49391E-03
6	2.67398E-01	5.16772E 02	2.90420E 03	-4.52750E 00	5.16772E 02	-4.52750E 00	-1.01181E 00	-3.03529E-01
	-4.56860E-04							
	9.80912E 03	1.97207E 04	8.14905E 04	8.44639E 04	5.40227E 00	9.87764E 00	7.70557E 04	7.65334E 04
7	2	2	3.50000E-02		5.99991E 01	2.95714E-01	4.92857E-02	1.80000E 02
	2.53232E-10	1.42056E-03	1.76894E-01	-9.63747E-03	1.05422E-12	-4.38600E-12	1.76894E-01	1.42056E-03
5	2.18510E-08	6.05533E 02	2.92413E 03	-4.87241E 00	6.05533E 02	-4.87241E 00	-8.11284E-01	-2.43404E-01
	-2.89929E-11							
	1.33273E 04	2.12746E 04	8.23544E 04	8.47388E 04	4.82309E-07	7.66321E-07	7.65657E 04	7.63576E 04
9	2	2	3.50000E-02		5.99991E 01	3.94286E-01	4.92857E-02	0.
	0.	-4.46818E-03	1.72649E-01	-1.04935E-02	-0.	-0.	1.72649E-01	-4.46818E-03
4	0.	4.28448E 02	2.89156E 03	-2.54718E 00	4.28448E 02	-2.54718E 00	-1.97618E 00	-5.92863E-01
	-0.							
	2.56213E 03	2.19206E 04	7.97122E 04	8.55199E 04	0.	0.	7.84625E 04	7.69384E 04
9	2	2	3.50000E-02		5.99991E 01	3.94286E-01	4.92857E-02	9.00000E 01
	2.77244E-03	-1.53606E-03	1.75539E-01	-1.07251E-02	2.46376E-06	-4.83512E-05	1.75539E-01	-1.53606E-03
3	2.27927E-01	5.16804E 02	2.91973E 03	-2.87516E 00	5.16804E 02	-2.87516E 00	-1.88611E 00	-5.65819E-01
	-2.89172E-04							
	5.52772E 03	2.40039E 04	8.06496E 04	8.61923E 04	5.09585E 00	7.92855E 00	7.80327E 04	7.70477E 04
9	2	2	3.50000E-02		5.99991E 01	3.94286E-01	4.92857E-02	1.80000E 02
	2.52804E-10	1.38684E-03	1.77898E-01	-1.08649E-02	1.02549E-12	-4.40186E-12	1.77898E-01	1.38684E-03
2	1.94148E-08	6.05565E 02	2.94004E 03	-3.18734E 00	6.05565E 02	-3.18734E 00	-1.81718E 00	-5.45171E-01
	-1.60275E-11							
	8.40141E 03	2.62023E 04	8.13309E 04	8.66714E 04	4.76208E-07	6.33211E-07	7.74726E 04	7.69902E 04
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COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
11	2	2	3.50000E-02		5.99991E 01	4.92857E-01	4.92857E-02	0.
	0.	-4.52083E-03	1.73786E-01	-1.26408E-02	-0.	-0.	1.73786E-01	-4.52083E-03
	0.	4.28483E 02	2.90940E 03	-9.13644E-01	4.28483E 02	-9.13644E-01	-2.63375E 00	-7.90135E-01
	-0.							
	-6.57607E 02	2.51424E 04	7.92555E 04	8.69956E 04	0.	0.	7.95864E 04	7.75442E 04
11	2	2	3.50000E-02		5.99991E 01	4.92857E-01	4.92857E-02	9.00000E 01
	2.76770E-03	-1.58062E-03	1.76697E-01	-1.28537E-02	2.10093E-06	-4.85430E-05	1.76697E-01	-1.58062E-03
	1.87820E-01	5.16840E 02	2.93798E 03	-1.19517E 00	5.16840E 02	-1.19517E 00	-2.68514E 00	-8.05527E-01
	-2.77857E-04							
	1.61517E 03	2.79186E 04	7.99968E 04	8.78876E 04	4.00534E 00	6.72721E 00	7.92015E 04	7.77817E 04
11	2	2	3.50000E-02		5.99991E 01	4.92857E-01	4.92857E-02	1.80000E 02
	2.52373E-10	1.35075E-03	1.79069E-01	-1.29935E-02	1.00473E-12	-4.41740E-12	1.79069E-01	1.35075E-03
	1.69422E-08	6.05603E 02	2.95856E 03	-1.47411E 00	6.05603E 02	-1.47411E 00	-2.75602E 00	-8.26824E-01
	-1.71078E-11							
	3.80406E 03	3.08018E 04	8.04806E 04	8.85801E 04	4.00270E-07	5.67856E-07	7.86476E 04	7.78894E 04
13	2	2	3.50000E-02		5.99991E 01	5.91429E-01	4.92857E-02	0.
	0.	-4.57717E-03	1.75163E-01	-1.53707E-02	-0.	-0.	1.75163E-01	-4.57717E-03
	-0.	4.28526E 02	2.93102E 03	7.52256E-01	4.28526E 02	7.52266E-01	-3.23196E 00	-9.69599E-01
	-0.							
	-3.58639E 03	2.80736E 04	7.89945E 04	8.84926E 04	-0.	-0.	8.08473E 04	7.83247E 04
13	2	2	3.50000E-02		5.99991E 01	5.91429E-01	4.92857E-02	9.00000E 01
	2.76294E-03	-1.62902E-03	1.78100E-01	-1.57046E-02	1.64032E-06	-4.87338E-05	1.78100E-01	-1.62902E-03
	1.47095E-01	5.16885E 02	2.96009E 03	5.17903E-01	5.16885E 02	5.17903E-01	-3.44399E 00	-1.03318E 00
	-4.39324E-04							
	-2.10038E 03	3.16366E 04	7.95135E 04	8.96345E 04	2.05092E 00	6.35451E 00	8.05843E 04	7.87368E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
13	2	2	3.50000E-02		5.99991E 01	5.91429E-01	4.92857E-02	1.80000E 02
	2.51941E-10	1.31067E-03	1.80492E-01	-1.59840E-02	9.72270E-13	-4.43250E-12	1.80492E-01	1.31067E-03
	1.44305E-08	6.05648E 02	2.98106E 03	2.72740E-01	6.05648E 02	2.72740E-01	-3.67727E 00	-1.10320E 00
	-3.39670E-11							
	-7.06860E 02	3.53153E 04	7.97697E 04	9.05766E 04	2.45931E-07	5.78669E-07	8.01255E 04	7.90730E 04
15	2	2	3.50000E-02		5.99991E 01	6.90000E-01	0.	0.
	0.	-4.63885E-03	1.76836E-01	-1.86375E-02	-0.	-0.	1.76836E-01	-4.63885E-03
	-0.	4.28579E 02	2.95731E 03	2.45754E 00	4.28579E 02	2.45754E 00	-3.79092E 00	-1.13729E 00
	-0.							
	-6.32264E 03	3.08129E 04	7.89243E 04	9.00650E 04	-0.	-0.	8.22680E 04	7.92842E 04
15	2	2	3.50000E-02		5.99991E 01	6.90000E-01	0.	9.00000E 01
	2.75816E-03	-1.68321E-03	1.79819E-01	-1.92557E-02	8.32547E-07	-4.89217E-05	1.79819E-01	-1.68321E-03
	1.05412E-01	5.16939E 02	2.98718E 03	2.27139E 00	5.16939E 02	2.27139E 00	-4.19523E 00	-1.25855E 00
	-8.05477E-04							
	-5.77838E 03	3.53178E 04	7.91836E 04	9.15123E 04	-9.33432E-01	6.95696E 00	8.22252E 04	7.99365E 04
15	2	2	3.50000E-02		5.99991E 01	6.90000E-01	0.	1.80000E 02
	2.51507E-10	1.26433E-03	1.82252E-01	-1.98425E-02	9.05017E-13	-4.44702E-12	1.82252E-01	1.26433E-03
	1.18440E-08	6.05705E 02	3.00888E 03	2.06090E 00	6.05705E 02	2.06090E 00	-4.62875E 00	-1.38864E 00
	-7.00206E-11							
	-5.36556E 03	3.99773E 04	7.91664E 04	9.27694E 04	-4.55684E-09	6.81359E-07	8.19810E 04	8.05958E 04

MAXIMUM STRESS = 8.22680E 04 THETA = 0. POINT 66

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
1	3	2	1.80000E-02		5.99825E 01	0.	5.00005E-02	0.
	0.	-4.48043E-03	1.76836E-01	-1.86375E-02	-0.	-0.	1.76836E-01	-4.48043E-03
	-0.	4.28698E 02	1.58379E 03	9.73412E 00	4.28698E 02	9.73412E 00	-1.53685E-01	-4.61074E-02
	-0.							
	2.09705E 04	2.66626E 04	8.71346E 04	8.88423E 04	-0.	-0.	7.87715E 04	7.89625E 04
1	3	2	1.80000E-02		5.99825E 01	0.	5.00005E-02	9.00000E 01
	2.75815E-03	-1.51953E-03	1.79819E-01	-1.92557E-02	8.32660E-07	-4.88580E-05	1.79819E-01	-1.51953E-03
	1.07466E-01	5.17082E 02	1.61203E 03	9.55657E 00	5.17082E 02	9.55657E 00	1.92954E-01	5.78882E-02
	-1.09569E-04							
	3.23000E 04	2.51536E 04	9.06294E 04	8.84854E 04	3.94126E 00	7.99938E 00	7.95591E 04	7.89725E 04
1	3	2	1.80000E-02		5.99825E 01	0.	5.00005E-02	1.80000E 02
	2.51499E-10	1.43299E-03	1.82252E-01	-1.98425E-02	9.05139E-13	-4.43235E-12	1.82252E-01	1.43299E-03
	1.39819E-08	6.05872E 02	1.63614E 03	9.33332E 00	6.05872E 02	9.33332E 00	5.13842E-01	1.54151E-01
	-9.52263E-12							
	4.31752E 04	2.41440E 04	9.37511E 04	8.80418E 04	6.00425E-07	9.53115E-07	8.12751E 04	7.87947E 04
3	3	2	1.80000E-02		5.99825E 01	1.26123E-01	1.02245E-01	0.
	0.	-4.51603E-03	1.79234E-01	-1.92327E-02	-0.	-0.	1.79234E-01	-4.51603E-03
	-0.	4.28773E 02	1.60320E 03	9.07682E 00	4.28773E 02	9.07682E 00	3.75200E-03	1.12404E-03
	0.							
	2.38902E 04	2.37513E 04	8.90874E 04	8.90458E 04	-0.	-0.	7.98686E 04	7.98644E 04
3	3	2	1.80000E-02		5.99825E 01	1.26123E-01	1.02245E-01	9.00000E 01
	2.75200E-03	-1.53314E-03	1.82150E-01	-1.77466E-02	1.76085E-06	-4.93634E-05	1.82150E-01	-1.53314E-03
	5.26480E-02	5.17156E 02	1.63094E 03	8.95777E 00	5.17156E 02	8.95777E 00	1.54841E-01	4.64542E-02
	2.23433E-04							
	3.15983E 04	2.58635E 04	9.14682E 04	8.97477E 04	7.06253E 00	-1.21275E 00	8.04652E 04	8.00148E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
3	3	2	1.80000E-02		5.99825E 01	1.26123E-01	1.02245E-01	1.80000E 02
	2.50944E-10	1.44151E-03	1.84527E-01	-1.64788E-02	9.72367E-13	-4.47761E-12	1.84527E-01	1.44151E-03
	9.76130E-09	6.05945E 02	1.65464E 03	8.78427E 00	6.05945E 02	8.78427E 00	2.77787E-01	8.33338E-02
	1.70697E-11							
	3.88078E 04	2.85194E 04	9.34676E 04	9.03811E 04	8.58400E-07	2.26189E-07	8.13324E 04	8.00281E 04
5	3	2	1.80000E-02		5.99825E 01	3.56735E-01	1.54490E-01	0.
	0.	-4.58409E-03	1.83574E-01	-1.82022E-02	-0.	-0.	1.83574E-01	-4.58409E-03
	-0.	4.28911E 02	1.63831E 03	7.98004E 00	4.28911E 02	7.98004E 00	1.06281E-01	3.18847E-02
	0.							
	2.57965E 04	2.18602E 04	9.16076E 04	9.04267E 04	-0.	-0.	8.18184E 04	8.17197E 04
5	3	2	1.80000E-02		5.99825E 01	3.56735E-01	1.54490E-01	9.00000E 01
	2.74056E-03	-1.55407E-03	1.85984E-01	-1.55711E-02	9.26122E-06	-5.03186E-05	1.85984E-01	-1.55407E-03
	-3.96727E-02	5.17277E 02	1.66204E 03	7.95913E 00	5.17277E 02	7.95913E 00	1.20774E-01	3.62338E-02
	3.90960E-04							
	3.09742E 04	2.65011E 04	9.30068E 04	9.16648E 04	5.03596E 00	-9.44404E 00	8.20296E 04	8.17039E 04
5	3	2	1.80000E-02		5.99825E 01	3.56735E-01	1.54490E-01	1.80000E 02
	2.49911E-10	1.46603E-03	1.87944E-01	-1.34552E-02	1.52245E-12	-4.56173E-12	1.87944E-01	1.46603E-03
	2.63186E-09	6.06054E 02	1.68245E 03	7.86925E 00	6.06054E 02	7.86925E 00	1.26451E-01	3.79317E-02
	2.78119E-11							
	3.60114E 04	3.13280E 04	9.41719E 04	9.27670E 04	6.61249E-07	-3.68820E-07	8.23037E 04	8.17371E 04
7	3	2	1.80000E-02		5.99825E 01	6.91837E-01	2.06735E-01	0.
	0.	-4.67970E-03	1.89224E-01	-1.54788E-02	-0.	-0.	1.89224E-01	-4.67970E-03
	-0.	4.29090E 02	1.68400E 03	6.61307E 00	4.29090E 02	6.61307E 00	1.19683E-01	3.59089E-02
	0.							
	2.60547E 04	2.16220E 04	9.42205E 04	9.28905E 04	-0.	-0.	8.42701E 04	8.41884E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
7	3	2	1.80000E-02		5.99825E 01	6.91837E-01	2.06735E-01	9.00000E 01
	2.72347E-03	-1.57956E-03	1.90769E-01	-1.30587E-02	2.18685E-05	-5.16607E-05	1.90769E-01	-1.57956E-03
6	-1.45645E-01	5.17428E 02	1.70087E 03	6.70334E 00	5.17428E 02	6.70334E 00	9.71874E-02	2.91572E-02
	3.53916E-04							
	3.05458E 04	2.69463E 04	9.50325E 04	9.39526E 04	-1.53741E 00	-1.46454E 01	8.40320E 04	8.37945E 04
7	3	2	1.80000E-02		5.99825E 01	6.91837E-01	2.06735E-01	1.80000E 02
	2.48370E-10	1.50715E-03	1.92047E-01	-1.11691E-02	2.39781E-12	-4.67932E-12	1.92047E-01	1.50715E-03
5	-5.72667E-09	6.06185E 02	1.71587E 03	6.70993E 00	6.06185E 02	6.70993E 00	7.96321E-02	2.38839E-02
	2.41934E-11							
	3.51516E 04	3.22022E 04	9.57685E 04	9.48839E 04	1.29877E-07	-7.66174E-07	8.39096E 04	8.35731E 04
9	3	2	1.80000E-02		5.99825E 01	1.13143E 00	2.58980E-01	0.
	0.	-4.79721E-03	1.95278E-01	-1.21490E-02	-0.	-0.	1.95278E-01	-4.79721E-03
4	-0.	4.29283E 02	1.73292E 03	5.16726E 00	4.29283E 02	5.16726E 00	9.78579E-02	2.93648E-02
	0.							
	2.56613E 04	2.20369E 04	9.68171E 04	9.57296E 04	-0.	-0.	8.68770E 04	8.68343E 04
9	3	2	1.80000E-02		5.99825E 01	1.13143E 00	2.58980E-01	9.00000E 01
	2.70031E-03	-1.60909E-03	1.95912E-01	-1.04149E-02	3.50615E-05	-5.32981E-05	1.95912E-01	-1.60909E-03
3	-2.37964E-01	5.17591E 02	1.74258E 03	5.35098E 00	5.17591E 02	5.35098E 00	7.70211E-02	2.31066E-02
	2.53373E-04							
	3.01813E 04	2.73287E 04	9.72381E 04	9.63823E 04	-8.52812E 00	-1.79123E 01	8.62055E 04	8.60373E 04
9	3	2	1.80000E-02		5.99825E 01	1.13143E 00	2.58980E-01	1.80000E 02
	2.46282E-10	1.56247E-03	1.96472E-01	-9.03077E-03	3.30783E-12	-4.82479E-12	1.96472E-01	1.56247E-03
2	-1.34685E-08	6.06325E 02	1.75195E 03	5.44330E 00	6.06325E 02	5.44330E 00	6.21295E-02	1.86309E-02
	1.77828E-11							
	3.48353E 04	3.25342E 04	9.76757E 04	9.69857E 04	-4.18938E-07	-1.07756E-06	8.57408E 04	8.54947E 04

TRW SYSTEMS

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
11	3	2	1.80000E-02		5.99825E 01	1.67551E 00	3.11224E-01	0.
	0.	-4.93681E-03	2.00987E-01	-8.95558E-03	0.	-0.	2.00987E-01	-4.93681E-03
	-0.	4.29466E 02	1.77899E 03	3.80828E 00	4.29466E 02	3.80828E 00	7.22211E-02	2.16767E-02
	0.							
	2.51967E 04	2.25218E 04	9.92340E 04	9.84311E 04	-0.	-0.	8.93414E 04	8.93256E 04
11	3	2	1.80000E-02		5.99825E 01	1.67551E 00	3.11224E-01	9.00000E 01
	2.57058E-03	-1.64454E-03	2.00864E-01	-7.87625E-03	4.60346E-05	-5.51745E-05	2.00864E-01	-1.64454E-03
	-2.98638E-01	5.17747E 02	1.78276E 03	4.04805E 00	5.17747E 02	4.04805E 00	5.82106E-02	1.74629E-02
	1.58373E-04							
	2.98417E 04	2.76857E 04	9.93654E 04	9.87186E 04	-1.36610E 01	-1.95266E 01	8.83107E 04	8.81974E 04
11	3	2	1.80000E-02		5.99825E 01	1.67551E 00	3.11224E-01	1.80000E 02
	2.43602E-10	1.62939E-03	2.00805E-01	-6.96361E-03	4.10097E-12	-4.99480E-12	2.00805E-01	1.62939E-03
	-1.92739E-08	6.06462E 02	1.78734E 03	4.19924E 00	6.06462E 02	4.19924E 00	4.79306E-02	1.43694E-02
	1.19021E-11							
	3.45799E 04	3.28047E 04	9.95627E 04	9.90305E 04	-8.50363E-07	-1.29118E-06	8.75536E 04	8.73758E 04
13	3	2	1.80000E-02		5.99825E 01	2.32408E 00	3.63469E-01	0.
	0.	-5.10271E-03	2.05871E-01	-6.22952E-03	0.	-0.	2.05871E-01	-5.10271E-03
	-0.	4.29624E 02	1.81831E 03	2.64857E 00	4.29624E 02	2.64857E 00	5.00622E-02	1.50309E-02
	0.							
	2.47951E 04	2.29409E 04	1.01295E 05	1.00739E 05	-0.	-0.	9.14545E 04	9.14523E 04
13	3	2	1.80000E-02		5.99825E 01	2.32408E 00	3.63469E-01	9.00000E 01
	2.63379E-03	-1.68943E-03	2.05218E-01	-5.64462E-03	5.37078E-05	-5.72709E-05	2.05218E-01	-1.68943E-03
	-3.22145E-01	5.17884E 02	1.81808E 03	2.90189E 00	5.17884E 02	2.90189E 00	4.17073E-02	1.25117E-02
	8.50258E-05							
	2.95437E 04	2.79990E 04	1.01236E 05	1.00773E 05	-1.63224E 01	-1.94715E 01	9.01706E 04	9.00977E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
13	3	2	1.80000E-02		5.99825E 01	2.32408E 00	3.63469E-01	1.80000E 02
	2.40282E-10	1.70481E-03	2.04696E-01	-5.10391E-03	4.70326E-12	-5.18763E-12	2.04696E-01	1.70481E-03
	-2.25149E-08	6.06584E 02	1.81919E 03	3.07879E 00	6.06584E 02	3.07879E 00	3.52441E-02	1.05620E-02
	7.09990E-12							
	3.43518E 04	3.30464E 04	1.01262E 05	1.00871E 05	-1.11935E-06	-1.38231E-06	8.91934E 04	8.90703E 04
15	3	2	1.80000E-02		5.99825E 01	3.07714E 00	4.15714E-01	0.
	0.	-5.29971E-03	2.09715E-01	-4.09275E-03	0.	-0.	2.09715E-01	-5.29971E-03
	-0.	4.29749E 02	1.84913E 03	1.73990E 00	4.29749E 02	1.73990E 00	3.26968E-02	9.82226E-03
	-0.							
	2.44804E 04	2.32694E 04	1.02911E 05	1.02547E 05	-0.	-0.	9.31164E 04	9.31192E 04
15	3	2	1.80000E-02		5.99825E 01	3.07714E 00	4.15714E-01	9.00000E 01
	2.58937E-03	-1.74746E-03	2.08754E-01	-3.83302E-03	5.80596E-05	-5.95954E-05	2.08754E-01	-1.74746E-03
	-3.13017E-01	5.17995E 02	1.84677E 03	1.97098E 00	5.17995E 02	1.97098E 00	2.83166E-02	8.49446E-03
	3.54523E-05							
	2.93019E 04	2.82531E 04	1.02756E 05	1.02441E 05	-1.67333E 01	-1.80464E 01	9.16863E 04	9.16413E 04
15	3	2	1.80000E-02		5.99825E 01	3.07714E 00	4.15714E-01	1.80000E 02
	2.36268E-10	1.78564E-03	2.07929E-01	-3.55156E-03	5.09312E-12	-5.40318E-12	2.07929E-01	1.78564E-03
	-2.32504E-08	6.06685E 02	1.84577E 03	2.14306E 00	6.06685E 02	2.14306E 00	2.46649E-02	7.38729E-03
	3.58070E-12							
	3.41615E 04	3.32480E 04	1.02680E 05	1.02406E 05	-1.22538E-06	-1.35800E-06	9.05673E 04	9.04856E 04
17	3	2	1.80000E-02		5.99825E 01	3.93469E 00	4.67959E-01	0.
	0.	-5.53116E-03	2.12521E-01	-2.54520E-03	0.	-0.	2.12521E-01	-5.53116E-03
	-0.	4.29841E 02	1.87146E 03	1.08189E 00	4.29841E 02	1.08189E 00	2.01148E-02	6.04790E-03
	-0.							
	2.42525E 04	2.35076E 04	1.04082E 05	1.03858E 05	-0.	-0.	9.43238E 04	9.43272E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
17	3	2	1.80000E-02		5.99825E 01	3.93469E 00	4.67959E-01	9.00000E 01
	2.53672E-03	-1.82126E-03	2.11423E-01	-2.46588E-03	5.97269E-05	-6.21726E-05	2.11423E-01	-1.82126E-03
	-2.82201E-01	5.18079E 02	1.86842E 03	1.26820E 00	5.18079E 02	1.26820E 00	1.82147E-02	5.46403E-03
	6.60104E-06							
	2.91195E 04	2.84448E 04	1.03902E 05	1.03700E 05	-1.55556E 01	-1.58000E 01	9.28335E 04	9.28066E 04
17	3	2	1.80000E-02		5.99825E 01	3.93469E 00	4.67959E-01	1.80000E 02
	2.31502E-10	1.86966E-03	2.10430E-01	-2.34192E-03	5.29252E-12	-5.64260E-12	2.10430E-01	1.86966E-03
	-2.20507E-08	6.06763E 02	1.86648E 03	1.41343E 00	6.06763E 02	1.41343E 00	1.64284E-02	4.91586E-03
	1.29720E-12							
	3.40133E 04	3.34048E 04	1.03784E 05	1.03602E 05	-1.20101E-06	-1.24906E-06	9.16409E 04	9.15888E 04
19	3	2	1.80000E-02		5.99825E 01	4.89674E 00	5.20204E-01	0.
	0.	-5.79832E-03	2.14436E-01	-1.50502E-03	0.	-0.	2.14436E-01	-5.79832E-03
	-0.	4.29904E 02	1.88648E 03	6.39735E-01	4.29904E 02	6.39735E-01	1.16487E-02	3.50789E-03
	-0.							
	2.40993E 04	2.36678E 04	1.04870E 05	1.04740E 05	-0.	-0.	9.51375E 04	9.51400E 04
19	3	2	1.80000E-02		5.99825E 01	4.89674E 00	5.20204E-01	9.00000E 01
	2.47510E-03	-1.91193E-03	2.13303E-01	-1.50264E-03	5.96231E-05	-6.50313E-05	2.13303E-01	-1.91193E-03
	-2.42062E-01	5.18138E 02	1.88368E 03	7.72892E-01	5.18138E 02	7.72892E-01	1.10989E-02	3.32943E-03
	-6.98372E-06							
	2.89910E 04	2.85799E 04	1.04710E 05	1.04587E 05	-1.35772E 01	-1.33186E 01	9.36435E 04	9.36280E 04
19	3	2	1.80000E-02		5.99825E 01	4.89674E 00	5.20204E-01	1.80000E 02
	2.25915E-10	1.95592E-03	2.12233E-01	-1.45756E-03	5.34928E-12	-5.90768E-12	2.12233E-01	1.95592E-03
	-1.97215E-08	6.06819E 02	1.88161E 03	8.79814E-01	6.06819E 02	8.79814E-01	1.04158E-02	3.11193E-03
	2.47900E-14							
	3.39050E 04	3.35193E 04	1.04591E 05	1.04476E 05	-1.09518E-06	-1.09610E-06	9.24268E 04	9.23949E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
21	3	2	1.80000E-02		5.99825E 01	5.96327E 00	5.72449E-01	0.
	0.	-6.10089E-03	2.15668E-01	-8.54657E-04	0.	-0.	2.15668E-01	-6.10089E-03
	-0.	4.29945E 02	1.89590E 03	3.63395E-01	4.29945E 02	3.63395E-01	6.34361E-03	1.91600E-03
	-0.							
	2.40033E 04	2.37683E 04	1.05363E 05	1.05292E 05	-0.	-0.	9.56477E 04	9.56491E 04
21	3	2	1.80000E-02		5.99825E 01	5.96327E 00	5.72449E-01	9.00000E 01
	2.40369E-03	-2.01924E-03	2.14544E-01	-8.67155E-04	5.86197E-05	-6.81963E-05	2.14544E-01	-2.01924E-03
	-2.02794E-01	5.18176E 02	1.89375E 03	4.46065E-01	5.18176E 02	4.46065E-01	6.40489E-03	1.92137E-03
	-1.10364E-05							
	2.89062E 04	2.86690E 04	1.05244E 05	1.05173E 05	-1.14707E 01	-1.10619E 01	9.41786E 04	9.41700E 04
21	3	2	1.80000E-02		5.99825E 01	5.96327E 00	5.72449E-01	1.80000E 02
	2.19431E-10	2.04452E-03	2.13443E-01	-8.49147E-04	5.31809E-12	-6.20021E-12	2.13443E-01	2.04452E-03
	-1.70420E-08	6.06857E 02	1.89199E 03	5.12557E-01	6.06857E 02	5.12557E-01	6.28786E-03	1.87363E-03
	-5.33545E-13							
	3.38307E 04	3.35978E 04	1.05145E 05	1.05076E 05	-9.56657E-07	-9.36896E-07	9.29674E 04	9.29487E 04
23	3	2	1.80000E-02		5.99825E 01	7.10816E 00	5.72449E-01	0.
	0.	-6.43021E-03	2.16416E-01	-4.82240E-04	-0.	-0.	2.16416E-01	-6.43021E-03
	-0.	4.29969E 02	1.90131E 03	2.05213E-01	4.29969E 02	2.05213E-01	3.29187E-03	1.00011E-03
	-0.							
	2.39481E 04	2.38262E 04	1.05647E 05	1.05610E 05	-0.	-0.	9.59413E 04	9.59419E 04
23	3	2	1.80000E-02		5.99825E 01	7.10816E 00	5.72449E-01	9.00000E 01
	2.32338E-03	-2.13946E-03	2.15299E-01	-4.80379E-04	5.73889E-05	-7.16058E-05	2.15299E-01	-2.13946E-03
	-1.71289E-01	5.18200E 02	1.89988E 03	2.47114E-01	5.18200E 02	2.47114E-01	3.54747E-03	1.06425E-03
	-1.02686E-05							
	2.88546E 04	2.87232E 04	1.05568E 05	1.05529E 05	-9.70621E 00	-9.32589E 00	9.45047E 04	9.45000E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
23	3	2	1.80000E-02		5.99825E 01	7.10816E 00	5.72449E-01	1.80000E 02
	2.12130E-10	2.13430E-03	2.14178E-01	-4.60860E-04	5.24796E-12	-6.51440E-12	2.14178E-01	2.13430E-03
	-1.46413E-08	6.06880E 02	1.89860E 03	2.78104E-01	6.06880E 02	2.78104E-01	3.66219E-03	1.08609E-03
	-6.61641E-13							
	3.37834E 04	3.36477E 04	1.05498E 05	1.05458E 05	-8.25657E-07	-8.01152E-07	9.33117E 04	9.33011E 04
25	3	2	1.80000E-02		5.99825E 01	8.25306E 00	5.72449E-01	0.
	0.	-6.76217E-03	2.16848E-01	-2.89540E-04	-0.	-0.	2.16848E-01	-6.76217E-03
	-0.	4.29983E 02	1.90414E 03	1.23399E-01	4.29983E 02	1.23399E-01	1.69863E-03	5.21852E-04
	-0.							
	2.39194E 04	2.38565E 04	1.05795E 05	1.05776E 05	-0.	-0.	9.60946E 04	9.60947E 04
25	3	2	1.80000E-02		5.99825E 01	8.25306E 00	5.72449E-01	9.00000E 01
	2.23923E-03	-2.26276E-03	2.15717E-01	-2.66184E-04	5.63482E-05	-7.50316E-05	2.15717E-01	-2.26276E-03
	-1.50412E-01	5.18213E 02	1.90327E 03	1.36930E-01	5.18213E 02	1.36930E-01	1.96399E-03	5.89259E-04
	-7.99505E-06							
	2.88260E 04	2.87532E 04	1.05748E 05	1.05726E 05	-8.50429E 00	-8.20817E 00	9.46854E 04	9.46829E 04
25	3	2	1.80000E-02		5.99825E 01	8.25306E 00	5.72449E-01	1.80000E 02
	2.04477E-10	2.22066E-03	2.14567E-01	-2.34348E-04	5.17582E-12	-6.82945E-12	2.14567E-01	2.22066E-03
	-1.28951E-08	6.06893E 02	1.90244E 03	1.41300E-01	6.06893E 02	1.41300E-01	2.13823E-03	6.29078E-04
	-5.95390E-13							
	3.37559E 04	3.36767E 04	1.05703E 05	1.05679E 05	-7.27422E-07	-7.05371E-07	9.35117E 04	9.35058E 04
27	3	2	1.80000E-02		5.99825E 01	9.39796E 00	5.72449E-01	0.
	0.	-7.09552E-03	2.17119E-01	-1.90680E-04	-0.	-0.	2.17119E-01	-7.09552E-03
	-0.	4.29991E 02	1.90561E 03	8.14385E-02	4.29991E 02	8.14385E-02	8.66598E-04	2.72049E-04
	-0.							
	2.39044E 04	2.38723E 04	1.05872E 05	1.05862E 05	-0.	-0.	9.61747E 04	9.61745E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT U	HARMONIC V	THICKNESS W	OMEGA(T)	RADIUS OMEGA(P)	S OMEGA	ARC DELTA(R)	THETA DELTA(Y)
	NBAR(P-T) M(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
27	3	2	1.80000E-02		5.99825E 01	9.39796E 00	5.72449E-01	9.00000E 01
	2.15121E-03	-2.38780E-03	2.15949E-01	-1.47664E-04	5.55708E-05	-7.84718E-05	2.15949E-01	-2.38780E-03
	-1.37962E-01	5.18220E 02	1.90516E 03	7.59593E-02	5.18220E 02	7.59593E-02	1.08571E-03	3.25800E-04
	-5.73511E-06							
	2.88101E 04	2.87699E 04	1.05848E 05	1.05836E 05	-7.77077E 00	-7.55836E 00	9.47858E 04	9.47844E 04
27	3	2	1.80000E-02		5.99825E 01	9.39796E 00	5.72449E-01	1.80000E 02
	1.96467E-10	2.30500E-03	2.14755E-01	-1.01788E-04	5.11490E-12	-7.14548E-12	2.14755E-01	2.30500E-03
	-1.17531E-08	6.06900E 02	1.90467E 03	6.12233E-02	6.06900E 02	6.12233E-02	1.25233E-03	3.63454E-04
	-4.75575E-13							
	3.37399E 04	3.36935E 04	1.05822E 05	1.05808E 05	-6.61757E-07	-6.44143E-07	9.36280E 04	9.36247E 04
29	3	2	1.80000E-02		5.99825E 01	1.05429E 01	5.72449E-01	0.
	0.	-7.42962E-03	2.17306E-01	-1.40845E-04	-0.	-0.	2.17306E-01	-7.42962E-03
	-0.	4.29996E 02	1.90638E 03	6.02939E-02	4.29996E 02	6.02939E-02	4.31516E-04	1.41399E-04
	-0.							
	2.38967E 04	2.38807E 04	1.05913E 05	1.05908E 05	-0.	-0.	9.62165E 04	9.62162E 04
29	3	2	1.80000E-02		5.99825E 01	1.05429E 01	5.72449E-01	9.00000E 01
	2.05928E-03	-2.51383E-03	2.16078E-01	-8.22597E-05	5.50242E-05	-8.19231E-05	2.16078E-01	-2.51383E-03
	-1.31616E-01	5.18224E 02	1.90620E 03	4.23126E-02	5.18224E 02	4.23126E-02	5.97251E-04	1.79269E-04
	-3.95621E-06							
	2.88013E 04	2.87791E 04	1.05904E 05	1.05897E 05	-7.38527E 00	-7.23875E 00	9.48416E 04	9.48408E 04
29	3	2	1.80000E-02		5.99825E 01	1.05429E 01	5.72449E-01	1.80000E 02
	1.88098E-10	2.38814E-03	2.14824E-01	-2.39344E-05	5.06754E-12	-7.46235E-12	2.14824E-01	2.38814E-03
	-1.10974E-08	6.06904E 02	1.90597E 03	1.41857E-02	6.06904E 02	1.41857E-02	7.35053E-04	2.08385E-04
	-3.61196E-13							
	3.37305E 04	3.37033E 04	1.05891E 05	1.05884E 05	-6.23209E-07	-6.09831E-07	9.36960E 04	9.36942E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
31	3	2	1.80000E-02		5.99825E 01	1.16878E 01	5.72449E-01	0.
	0.	-7.76411E-03	2.17452E-01	-1.16690E-04	-0.	-0.	2.17452E-01	-7.76411E-03
	-0.	4.29999E 02	1.90679E 03	5.00523E-02	4.29999E 02	5.00523E-02	2.02835E-04	7.27156E-05
	0.							
	2.38926E 04	2.38851E 04	1.05934E 05	1.05931E 05	-0.	-0.	9.62385E 04	9.62381E 04
31	3	2	1.80000E-02		5.99825E 01	1.16878E 01	5.72449E-01	9.00000E 01
	1.96342E-03	-2.64042E-03	2.16150E-01	-4.64883E-05	5.46486E-05	-8.53823E-05	2.16150E-01	-2.64042E-03
	-1.29507E-01	5.18226E 02	1.90679E 03	2.39098E-02	5.18226E 02	2.39098E-02	3.23241E-04	9.70623E-05
	-2.71926E-06							
	2.87963E 04	2.87843E 04	1.05935E 05	1.05931E 05	-7.24517E 00	-7.14446E 00	9.48729E 04	9.48725E 04
31	3	2	1.80000E-02		5.99825E 01	1.16878E 01	5.72449E-01	1.80000E 02
	1.79369E-10	2.47057E-03	2.14823E-01	2.18236E-05	5.03174E-12	-7.77990E-12	2.14823E-01	2.47057E-03
	-1.08107E-08	6.06905E 02	1.90674E 03	-1.34658E-02	6.06905E 02	-1.34658E-02	4.29102E-04	1.16685E-04
	-2.73448E-13							
	3.37249E 04	3.37090E 04	1.05932E 05	1.05928E 05	-6.05659E-07	-5.95531E-07	9.37362E 04	9.37353E 04
33	3	2	1.80000E-02		5.99825E 01	1.28327E 01	5.72449E-01	0.
	0.	-8.09880E-03	2.17579E-01	-1.06121E-04	-0.	-0.	2.17579E-01	-8.09880E-03
	-0.	4.30002E 02	1.90701E 03	4.55796E-02	4.30002E 02	4.55796E-02	8.03862E-05	3.59321E-05
	0.							
	2.38905E 04	2.38875E 04	1.05945E 05	1.05944E 05	-0.	-0.	9.62502E 04	9.62498E 04
33	3	2	1.80000E-02		5.99825E 01	1.28327E 01	5.72449E-01	9.00000E 01
	1.86361E-03	-2.76732E-03	2.16192E-01	-2.75038E-05	5.43857E-05	-8.88470E-05	2.16192E-01	-2.76732E-03
	-1.30321E-01	5.18227E 02	1.90713E 03	1.41430E-02	5.18227E 02	1.41430E-02	1.65310E-04	4.96742E-05
	-1.96012E-06							
	2.87934E 04	2.87873E 04	1.05953E 05	1.05951E 05	-7.27634E 00	-7.20375E 00	9.48909E 04	9.48907E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT U NBAR(P-T) M(P-T) SIGMA(P) +	HARMONIC V N(P) SIGMA(P) -	THICKNESS W N(T) SIGMA(T) +	OMEGA(T) N(R) SIGMA(T) -	RADIUS OMEGA(P) N(Y) SIGMA(P-T) +	S OMEGA QBAR(P) SIGMA(P-T) -	ARC DELTA(R) M(P) SIGMA(EFF) +	THETA DELTA(Y) M(T) SIGMA(EFF) -
33	3	2	1.80000E-02		5.99825E 01	1.28327E 01	5.72449E-01	1.80000E 02
	1.70277E-10	2.55257E-03	2.14782E-01	4.83364E-05	5.00409E-12	-8.09797E-12	2.14782E-01	2.55257E-03
	-1.08020E-08	6.06906E 02	1.90721E 03	-2.94934E-02	6.06906E 02	-2.94934E-02	2.41444E-04	6.04541E-05
	-2.17936E-13							
	3.37215E 04	3.37125E 04	1.05958E 05	1.05955E 05	-6.04146E-07	-5.96074E-07	9.37608E 04	9.37605E 04
35	3	2	1.80000E-02		5.99825E 01	1.39776E 01	5.72449E-01	0.
	0.	-8.43360E-03	2.17698E-01	-1.02992E-04	-0.	-0.	2.17698E-01	-8.43360E-03
	-0.	4.30005E 02	1.90713E 03	4.42689E-02	4.30005E 02	4.42689E-02	1.05400E-05	1.49463E-05
	0.							
	2.38894E 04	2.38890E 04	1.05952E 05	1.05951E 05	-0.	-0.	9.62570E 04	9.62565E 04
35	3	2	1.80000E-02		5.99825E 01	1.39776E 01	5.72449E-01	9.00000E 01
	1.75984E-03	-2.89440E-03	2.16217E-01	-1.84864E-05	5.41856E-05	-9.23158E-05	2.16217E-01	-2.89440E-03
	-1.33249E-01	5.18227E 02	1.90734E 03	9.50378E-03	5.18227E 02	9.50378E-03	6.67720E-05	2.01011E-05
	-1.60655E-06							
	2.87916E 04	2.87892E 04	1.05964E 05	1.05963E 05	-7.43247E 00	-7.37296E 00	9.49022E 04	9.49021E 04
35	3	2	1.80000E-02		5.99825E 01	1.39776E 01	5.72449E-01	1.80000E 02
	1.60822E-10	2.63429E-03	2.14718E-01	6.26027E-05	4.98086E-12	-8.41647E-12	2.14718E-01	2.63429E-03
	-1.10134E-08	6.06906E 02	1.90753E 03	-3.81258E-02	6.06906E 02	-3.81258E-02	1.15007E-04	2.25787E-05
	-1.95685E-13							
	3.37191E 04	3.37149E 04	1.05974E 05	1.05974E 05	-6.15481E-07	-6.08233E-07	9.37774E 04	9.37775E 04
37	3	2	1.80000E-02		5.99825E 01	1.51224E 01	5.72449E-01	0.
	-0.	-8.76847E-03	2.17817E-01	-1.04414E-04	-0.	-0.	2.17817E-01	-8.76847E-03
	-0.	4.30007E 02	1.90722E 03	4.48962E-02	4.30007E 02	4.48962E-02	-3.72736E-05	5.77225E-07
	0.							
	2.38886E 04	2.38900E 04	1.05956E 05	1.05956E 05	-0.	-0.	9.62615E 04	9.62611E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
37	3	2	1.80000E-02		5.99825E 01	1.51224E 01	5.72449E-01	9.00000E 01
	1.65210E-03	-3.02162E-03	2.16237E-01	-1.61938E-05	5.40044E-05	-9.57880E-05	2.16237E-01	-3.02162E-03
	-1.37914E-01	5.18227E 02	1.90750E 03	8.32422E-03	5.18227E 02	8.32422E-03	-7.72972E-06	-2.26402E-06
	-1.62534E-06							
	2.87903E 04	2.87905E 04	1.05972E 05	1.05972E 05	-7.69198E 00	-7.63176E 00	9.49107E 04	9.49107E 04
37	3	2	1.80000E-02		5.99825E 01	1.51224E 01	5.72449E-01	1.80000E 02
	1.51002E-10	2.71581E-03	2.14642E-01	6.78966E-05	4.95818E-12	-8.73536E-12	2.14642E-01	2.71581E-03
	-1.14225E-08	6.06906E 02	1.90779E 03	-4.13424E-02	6.06906E 02	-4.13424E-02	1.13246E-05	-8.47173E-06
	-2.08685E-13							
	3.37172E 04	3.37168E 04	1.05988E 05	1.05989E 05	-6.38449E-07	-6.30720E-07	9.37910E 04	9.37914E 04
39	3	2	1.80000E-02		5.99825E 01	1.62673E 01	5.72449E-01	0.
	-0.	-9.10339E-03	2.17939E-01	-1.09493E-04	-0.	-0.	2.17939E-01	-9.10339E-03
	-0.	4.30010E 02	1.90730E 03	4.70830E-02	4.30010E 02	4.70830E-02	-8.39553E-05	-1.34540E-05
	0.							
	2.38879E 04	2.38910E 04	1.05961E 05	1.05961E 05	-0.	-0.	9.62660E 04	9.62656E 04
39	3	2	1.80000E-02		5.99825E 01	1.62673E 01	5.72449E-01	9.00000E 01
	1.54037E-03	-3.14895E-03	2.16257E-01	-1.97962E-05	5.37986E-05	-9.92637E-05	2.16257E-01	-3.14895E-03
	-1.44339E-01	5.18228E 02	1.90767E 03	1.01774E-02	5.18228E 02	1.01774E-02	-8.49194E-05	-2.54392E-05
	-2.04765E-06							
	2.87838E 04	2.87920E 04	1.05981E 05	1.05982E 05	-8.05676E 00	-7.98092E 00	9.49196E 04	9.49197E 04
39	3	2	1.80000E-02		5.99825E 01	1.62673E 01	5.72449E-01	1.80000E 02
	1.40816E-10	2.79715E-03	2.14566E-01	6.47617E-05	4.93174E-12	-9.05468E-12	2.14566E-01	2.79715E-03
	-1.20445E-08	6.06906E 02	1.90808E 03	-3.94732E-02	6.06906E 02	-3.94732E-02	-1.01162E-04	-4.21545E-05
	-2.63031E-13							
	3.37151E 04	3.37188E 04	1.06003E 05	1.06005E 05	-6.74012E-07	-6.64270E-07	9.38058E 04	9.38065E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT U	HARMONIC V	THICKNESS W	OMEGA(T)	RADIUS OMEGA(P)	S OMEGA	ARC DELTA(R)	THETA DELTA(Y)
	NBAR(P-T) M(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
41	3	2	1.80000E-02		5.99825E 01	1.74122E 01	5.72449E-01	0.
	-0.	-9.43838E-03	2.18069E-01	-1.18928E-04	-0.	-0.	2.18069E-01	-9.43838E-03
	-0.	4.30012E 02	1.90742E 03	5.11304E-02	4.30012E 02	5.11304E-02	-1.49887E-04	-3.32716E-05
	0.							
	2.38868E 04	2.38923E 04	1.05967E 05	1.05968E 05	-0.	-0.	9.62724E 04	9.62719E 04
41	3	2	1.80000E-02		5.99825E 01	1.74122E 01	5.72449E-01	9.00000E 01
	1.42466E-03	-3.27641E-03	2.16285E-01	-3.05782E-05	5.35169E-05	-1.02744E-04	2.16285E-01	-3.27641E-03
	-1.52984E-01	5.18228E 02	1.90790E 03	1.57244E-02	5.18228E 02	1.57244E-02	-1.92478E-04	-5.77304E-05
	-2.98340E-06							
	2.87869E 04	2.87940E 04	1.05993E 05	1.05995E 05	-8.55437E 00	-8.44387E 00	9.49319E 04	9.49321E 04
41	3	2	1.80000E-02		5.99825E 01	1.74122E 01	5.72449E-01	1.80000E 02
	1.30264E-10	2.87825E-03	2.14498E-01	5.11763E-05	4.89619E-12	-9.37454E-12	2.14498E-01	2.87825E-03
	-1.29393E-08	6.06906E 02	1.90847E 03	-3.12987E-02	6.06906E 02	-3.12987E-02	-2.56702E-04	-8.87312E-05
	-3.71275E-13							
	3.37122E 04	3.37217E 04	1.06024E 05	1.06028E 05	-7.25725E-07	-7.11974E-07	9.38262E 04	9.38273E 04
43	3	2	1.80000E-02		5.99825E 01	1.85571E 01	5.72449E-01	0.
	-0.	-9.77347E-03	2.18214E-01	-1.35324E-04	0.	-0.	2.18214E-01	-9.77347E-03
	-0.	4.30015E 02	1.90762E 03	5.81478E-02	4.30015E 02	5.81478E-02	-2.63851E-04	-6.75236E-05
	0.							
	2.38849E 04	2.38946E 04	1.05978E 05	1.05980E 05	-0.	-0.	9.62834E 04	9.62829E 04
43	3	2	1.80000E-02		5.99825E 01	1.85571E 01	5.72449E-01	9.00000E 01
	1.30493E-03	-3.40409E-03	2.16332E-01	-5.23995E-05	5.30893E-05	-1.06230E-04	2.16332E-01	-3.40409E-03
	-1.64863E-01	5.18229E 02	1.90828E 03	2.69507E-02	5.18229E 02	2.69507E-02	-3.68980E-04	-1.10712E-04
	-4.65242E-06							
	2.87837E 04	2.87973E 04	1.06013E 05	1.06018E 05	-9.24523E 00	-9.07292E 00	9.49521E 04	9.49525E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
43	3	2	1.80000E-02		5.99825E 01	1.85571E 01	5.72449E-01	1.80000E 02
	1.19343E-10	2.95900E-03	2.14455E-01	2.19366E-05	4.84426E-12	-9.69517E-12	2.14455E-01	2.95900E-03
	-1.42247E-08	6.06907E 02	1.90908E 03	-1.36776E-02	6.06907E 02	-1.36776E-02	-5.02645E-04	-1.62390E-04
	-5.54823E-13							
	3.37077E 04	3.37263E 04	1.06057E 05	1.06063E 05	-8.00535E-07	-7.79986E-07	9.38584E 04	9.38603E 04
45	3	2	1.80000E-02		5.99825E 01	1.97020E 01	5.72449E-01	0.
	-0.	-1.01088E-02	2.18385E-01	-1.64322E-04	0.	-0.	2.18385E-01	-1.01088E-02
	-0.	4.30020E 02	1.90800E 03	7.05378E-02	4.30020E 02	7.05378E-02	-4.75628E-04	-1.31164E-04
	0.							
	2.38812E 04	2.38988E 04	1.05997E 05	1.06002E 05	-0.	-0.	9.63038E 04	9.63032E 04
45	3	2	1.80000E-02		5.99825E 01	1.97020E 01	5.72449E-01	9.00000E 01
	1.18119E-03	-3.53213E-03	2.16413E-01	-9.30789E-05	5.24131E-05	-1.09727E-04	2.16413E-01	-3.53213E-03
	-1.81783E-01	5.18231E 02	1.90894E 03	4.78791E-02	5.18231E 02	4.78791E-02	-6.77730E-04	-2.03377E-04
	-7.41964E-06							
	2.87781E 04	2.88032E 04	1.06049E 05	1.06056E 05	-1.02365E 01	-9.96167E 00	9.49874E 04	9.49882E 04
45	3	2	1.80000E-02		5.99825E 01	1.97020E 01	5.72449E-01	1.80000E 02
	1.08050E-10	3.03918E-03	2.14459E-01	-3.29253E-05	4.76563E-12	-1.00170E-11	2.14459E-01	3.03918E-03
	-1.60998E-08	6.06909E 02	1.91012E 03	1.94097E-02	6.06909E 02	1.94097E-02	-9.13841E-04	-2.85560E-04
	-8.46624E-13							
	3.37002E 04	3.37341E 04	1.06112E 05	1.06123E 05	-9.10110E-07	-8.78753E-07	9.39124E 04	9.39155E 04
47	3	2	1.80000E-02		5.99825E 01	2.08469E 01	5.72449E-01	0.
	-0.	-1.04444E-02	2.18601E-01	-2.17073E-04	0.	-0.	2.18601E-01	-1.04444E-02
	-0.	4.30025E 02	1.90871E 03	9.30444E-02	4.30025E 02	9.30444E-02	-8.77774E-04	-2.51993E-04
	0.							
	2.38740E 04	2.39065E 04	1.06035E 05	1.06044E 05	-0.	-0.	9.63426E 04	9.63419E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
47	3	2	1.80000E-02		5.99825E 01	2.08469E 01	5.72449E-01	9.00000E 01
	1.05338E-03	-3.66080E-03	2.16559E-01	-1.67200E-04	5.13335E-05	-1.13239E-04	2.16559E-01	-3.66080E-03
	-2.06733E-01	5.18236E 02	1.91013E 03	8.60127E-02	5.18236E 02	8.60127E-02	-1.22948E-03	-3.68954E-04
	-1.18432E-05							
	2.87681E 04	2.88136E 04	1.06111E 05	1.06125E 05	-1.17045E 01	-1.12659E 01	9.50504E 04	9.50520E 04
47	3	2	1.80000E-02		5.99825E 01	2.08469E 01	5.72449E-01	1.80000E 02
	9.63833E-11	3.11840E-03	2.14549E-01	-1.31173E-04	4.64543E-12	-1.03406E-11	2.14549E-01	3.11840E-03
	-1.88798E-08	6.06913E 02	1.91188E 03	7.86928E-02	6.06913E 02	7.86928E-02	-1.61539E-03	-4.95736E-04
	-1.29380E-12							
	3.36875E 04	3.37473E 04	1.06207E 05	1.06225E 05	-1.07284E-06	-1.02492E-06	9.40045E 04	9.40096E 04
49	3	2	1.80000E-02		5.99825E 01	2.19918E 01	5.72449E-01	0.
	-0.	-1.07808E-02	2.18901E-01	-3.15109E-04	0.	-0.	2.18901E-01	-1.07808E-02
	0.	4.30034E 02	1.91008E 03	1.34827E-01	4.30034E 02	1.34827E-01	-1.64610E-03	-4.82804E-04
	0.							
	2.38603E 04	2.39212E 04	1.06107E 05	1.06124E 05	0.	0.	9.64167E 04	9.64157E 04
49	3	2	1.80000E-02		5.99825E 01	2.19918E 01	5.72449E-01	9.00000E 01
	9.21458E-04	-3.79063E-03	2.16822E-01	-3.01344E-04	4.96189E-05	-1.16776E-04	2.16822E-01	-3.79063E-03
	-2.44479E-01	5.18244E 02	1.91226E 03	1.55028E-01	5.18244E 02	1.55028E-01	-2.22217E-03	-6.66823E-04
	-1.87187E-05							
	2.87502E 04	2.88325E 04	1.06224E 05	1.06249E 05	-1.39288E 01	-1.32355E 01	9.51640E 04	9.51667E 04
49	3	2	1.80000E-02		5.99825E 01	2.19918E 01	5.72449E-01	1.80000E 02
	8.43353E-11	3.19594E-03	2.14791E-01	-3.03766E-04	4.46257E-12	-1.06669E-11	2.14791E-01	3.19594E-03
	-2.30461E-08	6.06922E 02	1.91492E 03	1.82874E-01	6.06922E 02	1.82874E-01	-2.82063E-03	-8.56872E-04
	-1.95881E-12							
	3.36657E 04	3.37701E 04	1.06368E 05	1.06400E 05	-1.31661E-06	-1.24407E-06	9.41628E 04	9.41714E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
51	3	2	1.80000E-02		5.99825E 01	2.31367E 01	5.46327E-01	0.
	-0.	-1.11186E-02	2.19359E-01	-4.99756E-04	0.	-0.	2.19359E-01	-1.11186E-02
	0.	4.30048E 02	1.91269E 03	2.13464E-01	4.30048E 02	2.13464E-01	-3.11653E-03	-9.24451E-04
	0.							
	2.38338E 04	2.39493E 04	1.06244E 05	1.06278E 05	0.	0.	9.65585E 04	9.65570E 04
51	3	2	1.80000E-02		5.99825E 01	2.31367E 01	5.46327E-01	9.00000E 01
	7.85342E-04	-3.92257E-03	2.17295E-01	-5.43623E-04	4.69337E-05	-1.20352E-04	2.17295E-01	-3.92257E-03
	-3.02403E-01	5.18259E 02	1.91610E 03	2.79683E-01	5.18259E 02	2.79683E-01	-4.01189E-03	-1.20381E-03
	-2.90791E-05							
	2.87179E 04	2.88665E 04	1.06428E 05	1.06472E 05	-1.73386E 01	-1.62616E 01	9.53686E 04	9.53736E 04
51	3	2	1.80000E-02		5.99825E 01	2.31367E 01	5.46327E-01	1.80000E 02
	7.18978E-11	3.27056E-03	2.15299E-01	-6.04268E-04	4.18817E-12	-1.09972E-11	2.15299E-01	3.27056E-03
	-2.93118E-08	6.06938E 02	1.92014E 03	3.64315E-01	6.06938E 02	3.64315E-01	-4.89598E-03	-1.47882E-03
	-2.91562E-12							
	3.36281E 04	3.38095E 04	1.06647E 05	1.06702E 05	-1.68242E-06	-1.57444E-06	9.44357E 04	9.44501E 04
53	3	2	1.80000E-02		5.99825E 01	2.42033E 01	4.94081E-01	0.
	-0.	-1.14356E-02	2.20049E-01	-8.17929E-04	0.	0.	2.20049E-01	-1.14356E-02
	0.	4.30070E 02	1.91723E 03	3.48899E-01	4.30070E 02	3.48899E-01	-5.67152E-03	-1.69171E-03
	0.							
	2.37878E 04	2.39978E 04	1.06482E 05	1.06544E 05	0.	0.	9.68051E 04	9.68025E 04
53	3	2	1.80000E-02		5.99825E 01	2.42033E 01	4.94081E-01	9.00000E 01
	6.54655E-04	-4.04892E-03	2.18073E-01	-9.41599E-04	4.31583E-05	-1.23736E-04	2.18073E-01	-4.04892E-03
	-3.84129E-01	5.18284E 02	1.92241E 03	4.84461E-01	5.18284E 02	4.84461E-01	-6.95010E-03	-2.08533E-03
	-4.28526E-05							
	2.86648E 04	2.89223E 04	1.06762E 05	1.06839E 05	-2.21340E 01	-2.05469E 01	9.57049E 04	9.57133E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
53	3	2	1.80000E-02		5.99825E 01	2.42033E 01	4.94081E-01	1.80000E 02
	5.99496E-11	3.33547E-03	2.16181E-01	-1.07916E-03	3.81767E-12	-1.13102E-11	2.16181E-01	3.33547E-03
	-3.79249E-08	6.06965E 02	1.92835E 03	6.51120E-01	6.06965E 02	6.51120E-01	-8.15709E-03	-2.45627E-03
	-4.13072E-12							
	3.35692E 04	3.38714E 04	1.07085E 05	1.07176E 05	-2.18344E-06	-2.03045E-06	9.48649E 04	9.48882E 04
55	3	2	1.80000E-02		5.99825E 01	2.51653E 01	4.41837E-01	0.
	-0.	-1.17254E-02	2.21063E-01	-1.32328E-03	0.	0.	2.21063E-01	-1.17254E-02
	0.	4.30104E 02	1.92447E 03	5.63986E-01	4.30104E 02	5.63986E-01	-9.74687E-03	-2.91534E-03
	0.							
	2.37142E 04	2.40752E 04	1.06861E 05	1.06969E 05	0.	0.	9.71985E 04	9.71942E 04
55	3	2	1.80000E-02		5.99825E 01	2.51653E 01	4.41837E-01	9.00000E 01
	5.33424E-04	-4.16798E-03	2.19251E-01	-1.54463E-03	3.83107E-05	-1.26852E-04	2.19251E-01	-4.16798E-03
	-4.91410E-01	5.18322E 02	1.93196E 03	7.94786E-01	5.18322E 02	7.94786E-01	-1.14011E-02	-3.42067E-03
	-5.92205E-05							
	2.85845E 04	2.90068E 04	1.07268E 05	1.07395E 05	-2.83973E 01	-2.62039E 01	9.62147E 04	9.62279E 04
55	3	2	1.80000E-02		5.99825E 01	2.51653E 01	4.41837E-01	1.80000E 02
	4.88596E-11	3.38752E-03	2.17534E-01	-1.77255E-03	3.35900E-12	-1.15986E-11	2.17534E-01	3.38752E-03
	-4.89271E-08	6.07006E 02	1.94031E 03	1.06996E 00	6.07006E 02	1.06996E 00	-1.29041E-02	-3.87926E-03
	-5.51477E-12							
	3.34836E 04	3.39615E 04	1.07723E 05	1.07867E 05	-2.82030E-06	-2.61605E-06	9.54905E 04	9.55263E 04
57	3	2	1.80000E-02		5.99825E 01	2.60229E 01	3.89592E-01	0.
	-0.	-1.19891E-02	2.22499E-01	-2.07222E-03	0.	0.	2.22499E-01	-1.19891E-02
	0.	4.30152E 02	1.93523E 03	8.82786E-01	4.30152E 02	8.82786E-01	-1.57990E-02	-4.73225E-03
	-0.							
	2.36048E 04	2.41899E 04	1.07425E 05	1.07600E 05	0.	0.	9.77835E 04	9.77761E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
57	3	2	1.80000E-02		5.99825E 01	2.60229E 01	3.89592E-01	9.00000E 01
	4.22548E-04	-4.28111E-03	2.20922E-01	-2.40008E-03	3.25415E-05	-1.29698E-04	2.20922E-01	-4.28111E-03
	-6.23962E-01	5.18375E 02	1.94552E 03	1.23509E 00	5.18375E 02	1.23509E 00	-1.77140E-02	-5.31455E-03
	-7.67015E-05							
	2.84706E 04	2.91267E 04	1.07986E 05	1.08183E 05	-3.60850E 01	-3.32442E 01	9.69387E 04	9.69580E 04
57	3	2	1.80000E-02		5.99825E 01	2.60229E 01	3.89592E-01	1.80000E 02
	3.87115E-11	3.42525E-03	2.19441E-01	-2.72323E-03	2.82993E-12	-1.18620E-11	2.19441E-01	3.42525E-03
	-6.21747E-08	6.07062E 02	1.95667E 03	1.64433E 00	6.07062E 02	1.64433E 00	-1.94009E-02	-5.82705E-03
	-6.93948E-12							
	3.33664E 04	3.40850E 04	1.08596E 05	1.08812E 05	-3.58266E-06	-3.32564E-06	9.63482E 04	9.64001E 04
59	3	2	1.80000E-02		5.99825E 01	2.67759E 01	3.37347E-01	0.
	-0.	-1.22279E-02	2.24428E-01	-3.10380E-03	0.	0.	2.24428E-01	-1.22279E-02
	0.	4.30218E 02	1.95007E 03	1.32203E 00	4.30218E 02	1.32203E 00	-2.41428E-02	-7.23680E-03
	-0.							
	2.34539E 04	2.43481E 04	1.08203E 05	1.08471E 05	0.	0.	9.85912E 04	9.85787E 04
59	3	2	1.80000E-02		5.99825E 01	2.67759E 01	3.37347E-01	9.00000E 01
	3.22871E-04	-4.38950E-03	2.23136E-01	-3.53293E-03	2.61982E-05	-1.32266E-04	2.23136E-01	-4.38950E-03
	-7.77417E-01	5.18446E 02	1.96347E 03	1.81831E 00	5.18446E 02	1.81831E 00	-2.60718E-02	-7.82187E-03
	-9.31111E-05							
	2.83197E 04	2.92854E 04	1.08937E 05	1.09227E 05	-4.49141E 01	-4.14656E 01	9.78989E 04	9.79252E 04
59	3	2	1.80000E-02		5.99825E 01	2.67759E 01	3.37347E-01	1.80000E 02
	2.95842E-11	3.44753E-03	2.21931E-01	-3.94431E-03	2.26269E-12	-1.20996E-11	2.21931E-01	3.44753E-03
	-7.71661E-08	6.07136E 02	1.97768E 03	2.38223E 00	6.07136E 02	2.38223E 00	-2.77361E-02	-8.32623E-03
	-8.23939E-12							
	3.32161E 04	3.42434E 04	1.09717E 05	1.10025E 05	-4.43959E-06	-4.13442E-06	9.74513E 04	9.75220E 04

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
61	3	2	1.80000E-02		5.99825E 01	2.74245E 01	2.85102E-01	0.
	-0.	-1.24426E-02	2.26848E-01	-4.41777E-03	0.	0.	2.26848E-01	-1.24426E-02
	0.	4.30299E 02	1.96899E 03	1.88190E 00	4.30299E 02	1.88190E 00	-3.47543E-02	-1.04217E-02
	-0.							
	2.32619E 04	2.45491E 04	1.09195E 05	1.09581E 05	0.	0.	9.96226E 04	9.96023E 04
61	3	2	1.80000E-02		5.99825E 01	2.74245E 01	2.85102E-01	9.00000E 01
	2.35186E-04	-4.49370E-03	2.25860E-01	-4.92723E-03	1.97790E-05	-1.34539E-04	2.25860E-01	-4.49370E-03
	-9.43239E-01	5.18533E 02	1.98557E 03	2.53638E 00	5.18533E 02	2.53638E 00	-3.63506E-02	-1.09054E-02
	-1.06095E-04							
	2.81342E 04	2.94805E 04	1.10108E 05	1.10512E 05	-5.43669E 01	-5.04374E 01	9.90830E 04	9.91160E 04
61	3	2	1.80000E-02		5.99825E 01	2.74245E 01	2.85102E-01	1.80000E 02
	2.15522E-11	3.45411E-03	2.24945E-01	-5.40761E-03	1.69898E-12	-1.23097E-11	2.24945E-01	3.45411E-03
	-9.30628E-08	6.07225E 02	2.00284E 03	3.26673E 00	6.07225E 02	3.26673E 00	-3.77152E-02	-1.13186E-02
	-9.25214E-12							
	3.30363E 04	3.44332E 04	1.11060E 05	1.11479E 05	-5.34149E-06	-4.99882E-06	9.87756E 04	9.88665E 04
63	3	2	1.80000E-02		5.99825E 01	2.79686E 01	2.32857E-01	0.
	-0.	-1.26330E-02	2.29652E-01	-5.94307E-03	0.	0.	2.29652E-01	-1.26330E-02
	0.	4.30394E 02	1.99113E 03	2.53740E 00	4.30394E 02	2.53740E 00	-4.61955E-02	-1.38554E-02
	-0.							
	2.30553E 04	2.47662E 04	1.10362E 05	1.10875E 05	0.	0.	1.00831E 05	1.00800E 05
63	3	2	1.80000E-02		5.99825E 01	2.79686E 01	2.32857E-01	9.00000E 01
	1.60239E-04	-4.59298E-03	2.28956E-01	-6.50582E-03	1.38130E-05	-1.36497E-04	2.28956E-01	-4.59298E-03
	-1.10974E 00	5.18632E 02	2.01069E 03	3.35266E 00	5.18632E 02	3.35266E 00	-4.75218E-02	-1.42567E-02
	-1.14651E-04							
	2.79328E 04	2.96929E 04	1.11441E 05	1.11969E 05	-6.37753E 01	-5.95290E 01	1.00431E 05	1.00469E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
63	3	2	1.80000E-02		5.99825E 01	2.79686E 01	2.32857E-01	1.80000E 02
	1.46853E-11	3.44622E-03	2.28315E-01	-7.03024E-03	1.18127E-12	-1.24905E-11	2.28315E-01	3.44622E-03
	-1.08793E-07	6.07325E 02	2.03079E 03	4.24946E 00	6.07325E 02	4.24946E 00	-4.85400E-02	-1.45648E-02
	-9.89234E-12							
	3.28414E 04	3.46392E 04	1.12552E 05	1.13091E 05	-6.22724E-06	-5.86086E-06	1.00250E 05	1.00360E 05
65	3	2	1.80000E-02		5.99825E 01	2.84082E 01	1.80612E-01	0.
	-0.	-1.27969E-02	2.32582E-01	-7.38247E-03	0.	0.	2.32582E-01	-1.27969E-02
	0.	4.30492E 02	2.01441E 03	3.23377E 00	4.30492E 02	3.23377E 00	-4.40655E-02	-1.32176E-02
	-0.							
	2.31002E 04	2.47323E 04	1.11667E 05	1.12156E 05	0.	0.	1.02096E 05	1.02063E 05
65	3	2	1.80000E-02		5.99825E 01	2.84082E 01	1.80612E-01	9.00000E 01
	9.87111E-05	-4.68450E-03	2.32148E-01	-8.01455E-03	8.61345E-06	-1.38118E-04	2.32148E-01	-4.68450E-03
	-1.26414E 00	5.18733E 02	2.03657E 03	4.19940E 00	5.18733E 02	4.19940E 00	-4.79839E-02	-1.43953E-02
	-1.25162E-04							
	2.79299E 04	2.97071E 04	1.12876E 05	1.13409E 05	-7.25477E 01	-6.79120E 01	1.01826E 05	1.01858E 05
65	3	2	1.80000E-02		5.99825E 01	2.84082E 01	1.80612E-01	1.80000E 02
	9.04683E-12	3.42733E-03	2.31746E-01	-8.59091E-03	7.36613E-13	-1.26399E-11	2.31746E-01	3.42733E-03
	-1.23218E-07	6.07427E 02	2.05912E 03	5.25004E 00	6.07427E 02	5.25004E 00	-5.10293E-02	-1.53106E-02
	-1.05858E-11							
	3.28010E 04	3.46909E 04	1.14112E 05	1.14679E 05	-7.04148E-06	-6.64941E-06	1.01757E 05	1.01865E 05
67	3	2	1.80000E-02		5.99825E 01	2.87433E 01	1.28367E-01	0.
	-0.	-1.29286E-02	2.35142E-01	-7.63893E-03	0.	0.	2.35142E-01	-1.29286E-02
	0.	4.30579E 02	2.03479E 03	3.88779E 00	4.30579E 02	3.88779E 00	4.46008E-02	1.33812E-02
	-0.							
	2.47470E 04	2.30951E 04	1.13292E 05	1.12796E 05	0.	0.	1.03169E 05	1.03205E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
67	3	2	1.80000E-02		5.99825E 01	2.87433E 01	1.28367E-01	9.00000E 01
	5.11948E-05	-4.76204E-03	2.34940E-01	-8.39909E-03	4.12064E-06	-1.39381E-04	2.34940E-01	-4.76204E-03
	-1.39495E 00	5.18822E 02	2.05922E 03	4.98166E 00	5.18822E 02	4.98166E 00	3.91217E-02	1.17365E-02
	-1.46115E-04							
	2.95479E 04	2.80990E 04	1.14618E 05	1.14184E 05	-8.02028E 01	-7.47912E 01	1.03072E 05	1.03049E 05
67	3	2	1.80000E-02		5.99825E 01	2.87433E 01	1.28367E-01	1.80000E 02
	4.69207E-12	3.40423E-03	2.34750E-01	-9.09351E-03	3.57945E-13	-1.27561E-11	2.34750E-01	3.40423E-03
	-1.35328E-07	6.07517E 02	2.08387E 03	6.16224E 00	6.07517E 02	6.16224E 00	3.29994E-02	9.89896E-03
	-1.23467E-11							
	3.43620E 04	3.31398E 04	1.15954E 05	1.15587E 05	-7.74686E-06	-7.28957E-06	1.03158E 05	1.03093E 05
69	3	2	1.80000E-02		5.99825E 01	2.89739E 01	7.61223E-02	0.
	-0.	-1.30199E-02	2.36655E-01	-4.88595E-03	0.	0.	2.36655E-01	-1.30199E-02
	0.	4.30630E 02	2.04680E 03	4.40126E 00	4.30630E 02	4.40126E 00	3.48011E-01	1.04404E-01
	-0.							
	3.03686E 04	1.74793E 04	1.15645E 05	1.11778E 05	0.	0.	1.03846E 05	1.04144E 05
69	3	2	1.80000E-02		5.99825E 01	2.89739E 01	7.61223E-02	9.00000E 01
	1.81734E-05	-4.81624E-03	2.36619E-01	-5.48222E-03	8.90890E-07	-1.40269E-04	2.36619E-01	-4.81624E-03
	-1.49233E 00	5.18876E 02	2.07284E 03	5.59102E 00	5.18876E 02	5.59102E 00	3.86048E-01	1.15814E-01
	-1.22223E-04							
	3.59755E 04	2.16774E 04	1.17303E 05	1.13013E 05	-8.51707E 01	-8.06439E 01	1.04087E 05	1.03885E 05
69	3	2	1.80000E-02		5.99825E 01	2.89739E 01	7.61223E-02	1.80000E 02
	1.66563E-12	3.38731E-03	2.36585E-01	-6.05452E-03	7.97073E-14	-1.28377E-11	2.36585E-01	3.38731E-03
	-1.44288E-07	6.07570E 02	2.09902E 03	6.86812E 00	6.07570E 02	6.86812E 00	4.19684E-01	1.25905E-01
	-1.08056E-11							
	4.15258E 04	2.59820E 04	1.18944E 05	1.14281E 05	-8.21608E-06	-7.81587E-06	1.04560E 05	1.03759E 05

COMBINED HARMONIC RESULTS

POINT	SEGMENT	HARMONIC	THICKNESS		RADIUS	S	ARC	THETA
	U	V	W	OMEGA(T)	OMEGA(P)	OMEGA	DELTA(R)	DELTA(Y)
	NBAR(P-T)	N(P)	N(T)	N(R)	N(Y)	QBAR(P)	M(P)	M(T)
	M(P-T)							
	SIGMA(P) +	SIGMA(P) -	SIGMA(T) +	SIGMA(T) -	SIGMA(P-T) +	SIGMA(P-T) -	SIGMA(EFF) +	SIGMA(EFF) -
71	3	2	1.80000E-02		5.99825E 01	2.91000E 01	0.	0.
	-0.	-1.30682E-02	2.37000E-01	-1.37112E-04	-0.	0.	2.37000E-01	-1.30682E-02
	0.	4.30644E 02	2.04945E 03	4.69731E 00	4.30644E 02	4.69731E 00	7.73204E-01	2.31961E-01
	0.							
	3.82432E 04	9.60605E 03	1.18154E 05	1.09563E 05	0.	0.	1.04424E 05	1.05090E 05
71	3	2	1.80000E-02		5.99825E 01	2.91000E 01	0.	9.00000E 01
	-1.79606E-12	-4.84391E-03	2.37000E-01	-5.87195E-12	-2.99430E-14	-1.40763E-04	2.37000E-01	-4.84391E-03
	-1.54777E 00	5.18888E 02	2.07593E 03	5.94172E 00	5.18888E 02	5.94172E 00	9.15747E-01	2.74724E-01
	-9.21732E-07							
	4.57854E 04	1.18688E 04	1.20417E 05	1.10242E 05	-8.60041E 01	-8.59700E 01	1.05277E 05	1.04813E 05
71	3	2	1.80000E-02		5.99825E 01	2.91000E 01	0.	1.80000E 02
	2.46204E-19	3.38042E-03	2.37000E-01	1.37112E-04	4.10460E-21	-1.28830E-11	2.37000E-01	3.38042E-03
	-1.49378E-07	6.07581E 02	2.10253E 03	7.27373E 00	6.07581E 02	7.27373E 00	-1.05901E 00	3.17703E-01
	-8.90739E-14							
	5.33658E 04	1.41432E 04	1.22691E 05	1.10924E 05	-8.30043E-06	-8.29713E-06	1.06553E 05	1.04572E 05

MAXIMUM STRESS = 1.06553E 05 THETA = 1.80000E 02 POINT 137

LOAD NUMBER 1
NUMBER OF PLOTS = 10 PLOTTING TIME = 6.06 MINUTES

LOAD NO.	DELTA(Y)
1	-1.306825E-02

2.6 OPERATING PROCEDURES

2.6.1 Software Requirements

IBSYS Operating System Tape Version 13 and Calcomp Software.

2.6.2 Hardware Requirements

1. IBM 7094 Computer with 32K core.
2. Data channels and tape units for the software.
3. Standard keypunches, verifiers, card readers, and printers.
4. Calcomp Plotter Model 565.

2.6.3 Deck Set-up

The overlay structure and the program deck setup are shown in figures 2.11 and 2.12.

2.6.4 Tapes Required

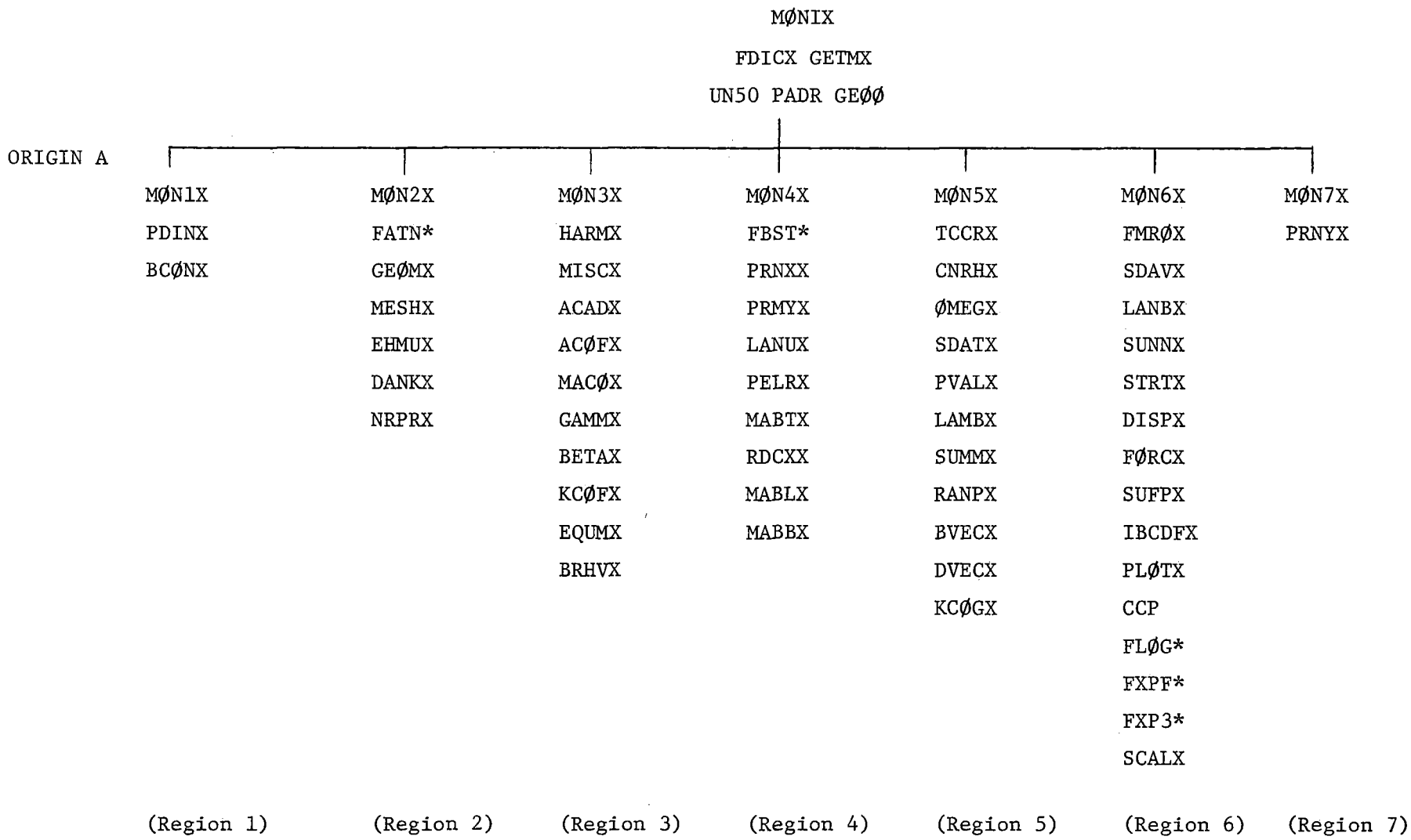
Logical units 03, 04, 09, 14, 15, 50 and SYSUT3 are required. Logical units 14 and 15 are used as scratch tapes. The use of units 03, 04, and 09 is problem dependent as described in the pre-operating and post-operating procedures. Unit SYSUT3 has been used as the overlay tape. Unit 50 is used as the plotting tape. The file specifications used are shown in table 2.2. The following units can be "GROUPED" for efficient core usage: Units 03 and 14, units 04 and 15. Only one unit in each GROUP is open at a time.

2.6.5 Input-Output Units

Logical unit 05 is used for input and logical unit 06 is used for output.

2.6.6 Special Pre-operating and Post-operating Procedures

1. The differences in the use of logical units 03, 04, and 09 are described in the following types of runs:



* IBM mathematical subroutine from library tape "included" with control card.

Figure 2.11 Program Overlay Structure

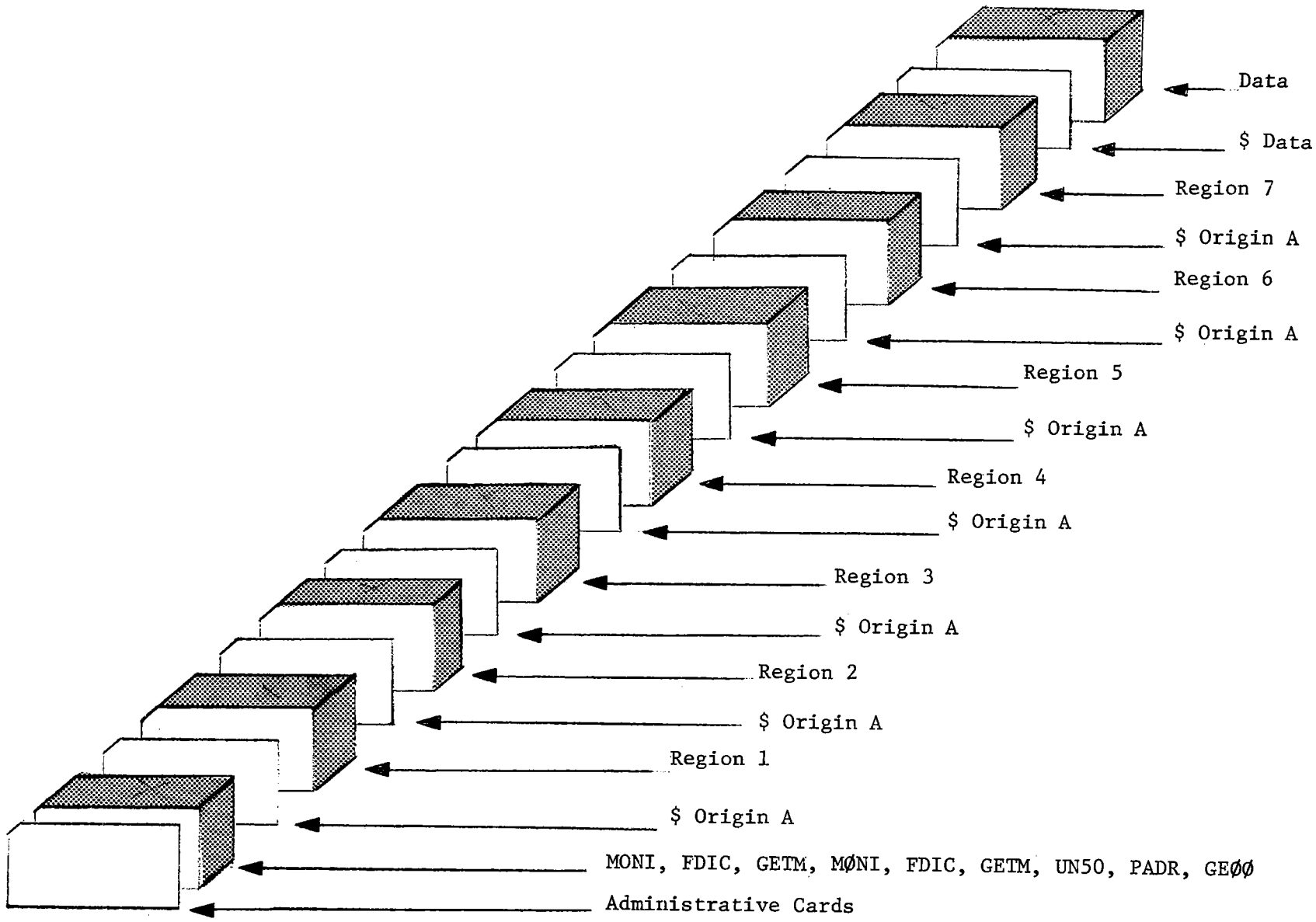


Figure 2.12 Program Deck Setup

a) In the first run of a particular problem.

03 - scratch tape

04 - tape which must be saved for a restart of this problem. This tape will be referred to as the prior solution tape.

09 - tape which must also be saved for a restart. This tape is referred to as the matrix solver or "L+U" tape.

b) In a "normal" restart run of a particular problem.

03 - Mount the prior solution tape which was saved on unit 04 from the previous run with the "ring out".

04 - Mount a tape with the "ring in". At the beginning of the run, the prior solution tape on unit 03 will be copied onto the unit 04 tape. The unit 04 tape will then be used as the prior solution tape for this run.

09 - Mount the matrix solver tape which was saved on unit 09 from the previous run with the "ring out".

This tape-copying procedure, done only for restart cases, will reduce the amount of lost time, should the prior solution tape be damaged, to one run.

c) In an "update" restart of a particular problem.

03 - Same as "normal" restart.

04 - Same as "normal" restart.

09 - Mount a tape with the "ring in". This tape will become the new matrix solver tape, and must be saved for a restart of this "update" restart problem.

Table 2.2

File Specifications Used at TRW Systems

```
UNIT05        ,IN1,READY,INPUT,BLK=467,BCD,NØLIST
UNIT06        ,ØU1,READY,ØUTPUT,BLK=467,BCD,NØLIST
UNIT03        ,LB4,READY,INØUT,BLK=256,BIN,NØLIST
UNIT04        ,IN2,READY,INØUT,BLK=256,BIN,NØLIST
UNIT09        ,CK1,READY,INØUT,BLK=256,BIN,NØLIST
UNIT10        ,UT3,READY,INØUT,BLK=256,BIN,NØLIST
UNIT14        ,CK2,READY,INØUT,BLK=256,BIN,NØLIST
UNIT15        ,LB2,READY,INØUT,BLK=256,BIN,NØLIST
UNIT50        ,PCH,READY,INØUT,BLK=257,BIN,LØW,HØLD,NØLIST
```

2. If a job stops for some unexpected reason such as maximum time exceeded, the following alternatives are available:

   a) If the matrix scale factors have been printed in the first run of a case, the case can be restarted as described in 7a. If any load levels have converged, the loading input data must be modified such that the restart loading values are equal to the sum of the original loading values and the incremented loading values.

      If the matrix scale factors have not been printed in the first run of a case, the case must be started from the beginning.

   b) If this run was a restart case, it can always be restarted if the proper tapes have been saved. As in 2.a above, the input loading data for the restart must reflect the number of load levels which have converged.

3. If a job is terminated with the error comment "NØ CØNVERGENCE AFTER 'NUMBER' ITERATIØNS ØN LØAD NØ. 'NUMBER'", the case can be restarted and the "update" option should be used. In this case a scratch tape should be mounted with the "ring in" on unit 09 and the "prior solution" tape should be mounted on unit 03.

2.6.7 Time and Printing Estimates

1. Timing estimates - .4 minutes to solve and increment the solution for one harmonic for case of 137 points.
2. Printing estimates consists of input data, geometry calculations, and convergence data.

NO of lines ≃ 200 x (number of harmonics + 1) + number of points x (one + sum of output options 1, 2, and 3) + D1 x (D2 x number of points printed) x (D3 x number of harmonics + D4 x number of values of theta considered in combined harmonic printing)

where

D1 =		Number of load levels in case
D2 =	6	Both forces and displacement are requested
=	5	Forces only are requested
=	4	Displacements only are requested
D3 =	0	Separate harmonic printing not requested
=	1	Separate harmonic printing requested
D4 =	0	Combined harmonic printing not requested
=	1	Combined harmonic printing requested

2.6.8 Error Messages

This section contains those messages which may be printed during program execution. Each error message will be described in the following manner:

a) Message printed
b) Interpretation
c) Action taken by program.

The first eighteen error messages concern the input data. The last two messages concern the iterative solution.

1. (a) NUMBER ØF SEGMENTS EXCEEDS MAXIMUM SIZE.
   (b) The number of segments specified is greater than 7.
   (c) Terminate execution.

2. (a) NUMBER ØF FØURIER HARMØNICS EXCEEDS MAXIMUM.
   (b) The number of segments specified is greater than 7.
   (c) Terminate execution.

3. (a) TØØ MANY PØINTS FØR INDIVIDUAL PØINT PLØTTING
   (b) The number of points input for "Individual point plotting" is greater than 10.
   (c) Terminate execution after reading remainder of input data.

4. (a) TØØ MANY LØADINGS INPUT FØR PLØTTING
   (b) The number of load levels for which plotting information has been input is greater than 10.
   (c) Same as 3c.

5. (a) CØNVERGENCE CRITERIØN NØT GREATER THAN ZERØ
   (b) One of the two following input variables was equal to zero: The maximum number of harmonic loops or the value of "β".
   (c) Same as 3c.

6. (a) BØUNDARY CØNDITIØNS NØT IN ØRDER.
   (b) Either 4 boundary conditions for a particular harmonic were not input, or the harmonic value input with the boundary conditions did not agree with the corresponding value in the list of harmonics.
   (c) Same as 3c.

7. (a) BØUNDARY CØNDITIØNS DUPLICATED, HARMØNIC = "INTEGER".
   (b) For the harmonic listed, the same boundary condition number is input more than once.
   (c) Same as 3c.

8. (a) SEGMENT "I" REQUESTS TØØ MANY PØINTS
   (b) Segment "I" specified more than 73 intervals
   (c) Same as 3c.

9. (a) NUMBER ØF PØINTS REQUESTED EXCEEDS CASE LIMIT.

   (b) The number of points requested for the shell was greater than 300.

   (c) Same as 3c.

10. (a) SEGMENT "I" -- TØØ MANY LEADING AND TRAILING INTERVALS.

    (b) The sum of the number of leading and trailing intervals is greater than the total number of intervals requested for segment "I".

    (c) Same as 3c.

11. (a) GEØMETRY DATA NØT IN ØRDER, SEGMENT "I"

    (b) The input segment number was not the same as the "I^{th}" segment read.

    (c) Same as 3c.

12. (a) LØAD DATA NØT IN ØRDER - SEGMENT "I" HARMØNIC "J"

    (b) Either the input segment number did not equal "I" or for the "J^{th}" harmonic read, the input harmonic value did not equal the "J^{th}" harmonic list value.

    (c) Same as 3c.

13. (a) ELASTIC SUPPØRT DATA NØT IN ØRDER - SEGMENT "I" HARMØNIC "I"

    (b) Same as 12b.

    (c) Same as 3c.

14. (a) RESTART ØPTION 4 SPECIFIED WHEN FIRST HARMØNIC NØT EQUAL TØ ZERØ
    TERMINATE CASE

    (b) "Update" option may be used only when first harmonic equals zero.

    (c) Terminate case.

15. (a) INPUT HARMØNIC VALUE NØT EQUAL HARMØNIC LIST VALUE

    (b) The matrix scale factor harmonic identification did not correspond with the harmonic list.

    (c) Same as 3c.

16. (a) EXECUTIØN TERMINATED, "I" INPUT ERRØRS

    (b) These were "I" input errors. Note that the option used to terminate after reading the input data is considered in the error count.

    (c) Terminate case.

17. (a) SEGMENT "J" -- ELASTICITY, THICKNESS, ØR MU = 0.

    (b) In segment "J" one of the input end points for Young's modulus (E), thickness (t), or Poisson's ratio (μ) is equal to zero.

    (c) Terminate case.

18. (a) EXECUTIØN TERMINATED BY INPUT ØPTIØN

    (b) Second restart option = 1: Terminate case after performing geometry calculations.

    (c) Execution terminated.

19. (a) NØ CØNVERGENCE AFTER "I" ITERATIØNS ØN LØAD NØ. "J"

    (b) The "J^{th}" load level has not converged after "I", an input parameter, iterations.

    (c) Print the output specified in the Output Section, then terminate the case.

20. (a) SØLUTION HAS DIVERGED ØR MACHINE ERRØR HAS ØCCURRED
    PRIØR SØLUTIØN TAPE STILL GØØD
    TERMINATE CASE
    INCREMENTAL SØLUTIØN FØR M = "J"

    (b) One of the four incremental unknowns "u", "v", "w", or "ω_θ" has a value greater than 100.

2.6.9 Case Limitations

1. Maximum number of harmonics considered in each case . . 7
2. Maximum number of segments in each case 7
3. Maximum number of points in entire shell 300
4. Maximum number of points in each segment 74
   (number of intervals plus one)
5. Number of load levels in any one given run 10

2.6.10 Plotting and Printing

This section contains instructions for implementing installation plotting subroutines and changing the number of points printed on each page.

1. It is anticipated that each installation will have to implement its own Calcomp plotting subroutines.

   If the plotting capability is not desired, the program may be used with no changes. If the plotting options are exercised in this case, the program will print a message indicating that the installation plotting subroutines have not been included. Dummy subroutines have been inserted in front of the TRW Systems subroutines CCP and SCAL.

   If the plotting capability is desired, the subroutines PLØTX, CCP, and SCAL may be replaced by their installation equivalent. Note that the subroutines UN50, PADR, and GEØØ are only required by CCP. The following instructions indicate the subroutine which should be modified to use the installation plotting subroutines.

   Calls to Calcomp plotting subroutines are made in region six, subroutine SUFPX in three separate places.

   a. Cards SUFP1160 and SUFP1170. The variable vs arc length is plotted for given values of theta. This call to PLØTX is multicurve type plotting. The arguments for PLOTX are defined below.

SP	-	independent variable of dimension (91)
PB	-	dependent variable of dimension (75,5)
XSCAL	-	variable indicating plotting paper width
NTE	-	number of curves in this plot
IP	-	number of points for each curve in this plot
BTITLE	-	bottom title of dimension (12)
YTITLE	-	side title of dimension (12)
TTITLE	-	top title of dimension (12)
ATITLE	-	annotation title of dimension (5,5)
NCX	-	symbol frequency for curves
LAST	-	1 indicating not the last plot
NPSG	-	dimension of PB=75
PLTIM	-	cell to obtain estimated plotting time from plotting subroutine.

The subroutine PLØT performs the scaling by calling SCAL and the plotting by calling CCP.

b. Cards SUFP1890 and SUFP1900. The variable is plotted around the circumference. This is single curve plotting. The arguments are defined below.

SP	-	independent variable of maximum dimension (91)
TP	-	dependent variable of maximum dimension (91)
XSCAL	-	variable indicating plotting paper width
IØNE	-	equals one indicating one curve
NTE	-	number of points in this curve
BTITLE	-	bottom title of dimension (12)
YTITLE	-	side title of dimension (12)
TTITLE	-	top title of dimension (12)
ATITLE	-	not used for single curve mode.
NCX	-	symbol frequency for curve
LAST	-	1 indicating not last plot
MTHE	-	dimension of TP = 91
PLTIM	-	cell to obtain estimated plotting time from plotting subroutine.

As in a., the scaling and plotting is performed by PLØT.

c. Card SUFP1990. This call to CCP terminates the plotting tape.

2. If an installation uses a different length of paper than that used at TRW Systems (40 lines per page), the number of points printed on each page can be changed. Instructions are given in region six subroutine STRTX.

2.7 Program Description

2.7.1 Introduction

This program has been written primarily in FORTRAN IV version 13 for use on an IBM 7094 computer. Those subroutines not in FORTRAN IV have been included as required by the Calcomp plotting subroutine CCP.

Because of the size of the problem, the program consists of large regions stored on magnetic tape and connected by a logical monitor which remains in the computer core at all times. Whenever the function performed by a particular region is desired, that region is brought into the computer core. Portions of the data required by the regions are stored in core while the remaining portions are saved on tape. The program will be described by first considering each region separately. The flow of the program will then be discussed in terms of all the regions.

2.7.2 Region Summaries

This section contains a brief description of each region in the program.

1.	MAIN	The MONI subroutine calls each of the monitors in each region.
2.	Region One	In region one the input data is read and printed.
3.	Region Two	The S-mesh, sine and cosine of phi, and material properties of each segment are calculated and optionally printed. Additionally, certain "restart" and "update" calculations are made including the calculation of the number of rows in each record of the "U" and "L" matrices and the copying of the prior solution tape.
4.	Region Three	The matrix of the governing equations of equilibrium is generated for each of the harmonics.
5.	Region Four	The matrix solver (L + U) tape is generated and the incremental solution is obtained for each harmonic.

6. Region Five — The following functions are performed in region five:
   1. Generate and increment the prior solution tape.
   2. Test for convergence.
   3. Build the new right hand vector.
   4. Increment the loading after each convergence.
7. Region Six — The forces, displacements, rotations, and stresses are calculated, printed, and plotted according to the input specifications.
8. Region Seven — Used in program checkout. This region is not entered in normal program execution.

2.7.3 The Program Flow

The flow of control will be described for an "original" start, a "normal" restart, and an "update" restart. Before considering these three types, however, procedures denoted by several phrases should be defined.

The phrase "special iterations" denotes the number of iterations performed to obtain a converged solution for the harmonic M = 0. Specifically, the governing equations of equilibrium ("K" matrix) for M = 0 will be solved once for each special iteration.

The flow for each special iteration is as follows:

1. Enter region three and generate the "K" matrix for the zero harmonic using the special iteration forces obtained from the previous iteration(s). These forces are used in the "modified 'A' coefficients".
2. Enter region four and solve the following equation for M = 0

$$[K]\{X\} = \{R\}$$

where

[K] - "K" matrix

{X} - solution vector

{R} - right hand vector

3. Enter region five, build the new right hand vector for M = 0, obtain the "special iteration" forces, reduce the number of remaining special iterations by one, and go back to step 1.

   The flag containing the number of remaining special iterations is used in regions three, four, and five to differentiate between special iterations and "ordinary iterations".

The phrase "ordinary iterations" denotes the procedure followed to obtain an incremental solution for one harmonic. The program flow is a loop which continues until the solution converges, the solution diverges, or the maximum number of harmonic loops is exceeded.

1. Enter region four with flag set for ordinary iteration, perform matrix multiplication and back substitution to obtain incremental solution for "Ith" harmonic, and test for divergence. If incremental solution has diverged, the program prints a message, prints the incremental solution, and terminates the execution of the case.
2. Enter region five, add the incremental solution to the prior solution, build the new right hand vector for the "I + 1th" harmonic, and test for convergence. If solution hasn't converged, return to 1. If solution has converged, the program will increment the loading if all load increments have not been performed, build the right hand vector for the first harmonic in the list using the incremented loading and transfer control to region six, where the converged solution will be printed. Region six will send control to 1.

The phrase "zero th iteration" denotes the procedure followed in the transition between special iterations and ordinary iterations.

1. Enter region three and build the "K" matrix for each harmonic.
2. Enter region four and build the "U" and "L" tape. This tape contains the "U" and "L" matrices described in region four.
3. Enter region five, initialize the prior solution tape, and build the right hand vector for M = 0.

The three types of runs (original, restart, and update) enter region one to read the input data and region two to build the case geometry. The program flow will be described assuming region two has just been left.

Flow of an Original Start. In an original start, the program performs the special iterations, the zero th iteration, and the ordinary iterations for each load level.

Flow of a Normal Restart. In a normal restart, the program enters region five and builds the right hand vector for M = 0. The ordinary iterations are then performed.

Flow of an Update Restart. The program enters region five, builds the right hand vector for M = 0, and calculates the special iteration forces for M = 0. The zero th iteration is then performed with the following addition to region three. Before the "K" matrix is built for harmonic = M, the special iteration forces are built for the harmonic = 2M, if it exists in the list of harmonics. After the zero-th iteration is completed, the ordinary iterations are performed.

2.7.4 Blank CØMMØN and Variable - Symbol Definitions

This section contains the definitions of the variables in the blank COMMON block and the engineering symbol corresponding to those variables.

VARIABLE	SYMBOL	DEFINITION OF VARIABLE
NSGMTS		Number of segments in case (INPUT)
KS		Number of harmonics in case (Input)
ISGMT		Current segment number in regions one, two, and three.
IFTNØ		Current harmonic value in regions one, two, and three.
LØADNØ		Index used to determine if the current loading should be printed.
LDNØPR		Index of next loading to be plotted.

VARIABLE	SYMBOL	DEFINITION OF VARIABLE
NLØAD		Number of loading in this case (Input).
KKKKK		Overlay flag indicating current region.
PHI(7)		Angle PHI for each segment.
SINP(7)		SINE (PHI) for each segment.
CØSP(7)		CØSINE (PHI) for each segment.
NPSEG(7)		Number of points in each segment.
LSP(7)		Index of starting point for each segment.
MLIST(7)		Harmonic values for case (Input).
ECR(7)	e_r	Eccentricity between current and following segment, R-component (Input).
ECY(7)	e_y	Eccentricity between current and following segment, Y-component (Input).
IØPT(14)		Input options for case (Input).
IRES(10)		Restart options for case (7 input).
NREC(21)		Number or rows in each logical record of K, U, and L matrices.
INTF(10)		Internal flags defined by the following:
INTF(1)		The number of special iterations for the zero harmonic (Input).
INTF(2)		The number of special iterations remaining to be performed. Initially, is equal to INTF(1).
INTF(3)		Determines whether or not special iteration forces may be used in building up "K" matrix = 0 Do not use them. > 0 Do use them.

VARIABLE	SYMBOL	DEFINITION OF VARIABLE
INTF(4)		Overlay flag for region 4 = 1 special iteration = 2 ordinary iteration
INTF(5)		Index of harmonic under consideration.
INTF(6)		The number of ordinary iterations which have been performed at the current load level.
INTF(7)		The number of load increments performed.
INTF(8)		Counter controlling the printing of the beta values after each complete harmonic loop.
INTF(9)		Not used.
INTF(10)		Not used.
NSGPL(10)		Segment plotting flags (7 input).
NPTPT(10)		Individual point plotting flags. Flags are input by the point number in the particular segment. Internally, they are stored by the point number in the entire shell.
NLDPL(10)		Load plotting flags (Input).
EI(2,7)	E	Initial and final values of Young's modulus (E) for each segment (Input).
HI(2,7)	t	Initial and final values of thickness (t) for each segment (Input).
FMUI(2,7)	μ	Initial and final values of Poisson's ratio (μ) for each segment (Input).
RI(7)	r	Initial value of the radius of the segment (Input).

The next four variables contain the following information for the IJK^{th} segment and IJH^{th} harmonic

VARIABLE	SYMBOL	DEFINITION OF VARIABLE
XLDX(1,IJK,IJH)	$\overline{X}$	Circumferential loading ($\overline{X}$).
XLDX(2,IJK,IJH)	$\overline{Y}$	Meridional loading ($\overline{Y}$).
XLDX(3,IJK,IJH)	$\overline{Z}$	Normal loading ($\overline{Z}$).
XLDX(4,IJK,IJH)	$\overline{R}$	Radial loading ($\overline{R}$).
XLDX(5,IJK,IJH)	$\overline{a}$	Axial loading ($\overline{a}$).
FLDI(5,7,7)		Initial loading values for each segment and each harmonic (Input).
FLDF(5,7,7)		Final loading values for each segment and each harmonic (Input).
DLDI(5,7,7)		Initial incremental loading values for each segment and each harmonic (Input).
DLDF(5,7,7)		Final incremental loading values for each segment and each harmonic (Input).
FMPØ(2,7,7)	M_{ϕ}^{a}	Initial and incremental values of the applied, discrete, meridional moment for each segment and each harmonic (Input).
FNRØ(2,7,7)	N_{R}^{a}	Initial and incremental values of the applied, discrete, radial force for each segment and each harmonic (Input).
FNYØ(2,7,7)	N_{Y}^{a}	Initial and incremental values of the applied, discrete, axial force for each segment and each harmonic (Input).
FNPTØ(2,7,7)	$N_{\phi\theta}^{a}$	Initial and incremental values of the applied, discrete, shear force for each segment and each harmonic (Input).

VARIABLE	SYMBOL	DEFINITION OF VARIABLE
ECRS(7,7)	e_r^s	Eccentricity, center of gravity-offset, R-component for each segment and each harmonic (Input).
ECYS(7,7)	e_y^s	Eccentricity, center of gravity-offset, Y-component for each segment and each harmonic (Input).
RSS(7,7)	R_s	Support radius for each segment and each harmonic (Input).
SCF(16,7,7)	C_I	Sixteen stiffness coefficients for each segment and each harmonic (Input).
IBC(4,7,2)		Index of 4 boundary conditions for each harmonic and the leading and trailing edge (Input).
BC(4,7,2)		Four boundary conditions for each harmonic and the leading and trailing edge (Input).
DLBC(4,7,2)		Increment to four boundary conditions for each harmonic and the leading and trailing edge (Input).
S(300)		S-mesh for all points in shell.
FNTH(300)	N_{θ_0}	Circumferential force (N_θ) for zero harmonic.
FNPH(300)	N_{ϕ_0}	Meridional force for zero harmonic.
ØPHI(300)	Ω_{ϕ_0}	$\Omega_{\phi_0} = 1/2 \sum_M (\omega_{\phi_M})^2$
ØTHE(300)	ω_{θ_0}	Meridional rotation (ω_θ) for zero harmonic.
STP(12,7)		Storage for solution matrix scale factors for each harmonic.

VARIABLE	SYMBOL	DEFINITION OF VARIABLE
AK(140,23)		Storage for one logical record of 'K' matrix.
AU(140,23)		Storage for one logical record of 'U' matrix.
AL(200,13)		Storage for one logical record of 'L' matrix.
RHV(600)		Storage for right hand vector for one segment.
SAVE(5,10)		Information saved for each load level.

2.7.5 Region Description

This section contains the equivalence definition and the named CØMMØN block definition used in each region.

1. Equivalenced variable definition
   The definitions for regions 1 through 6 are shown in Figures 2.13 through 2.16. The definitions for region 1 and region 2 are both in figure 2.13.

2. Named CØMMØN Definitions

   This section contains the named CØMMØN block definitions for each region in the program. The definitions for regions one through six contain those CØMMØN blocks used exclusively in that region.

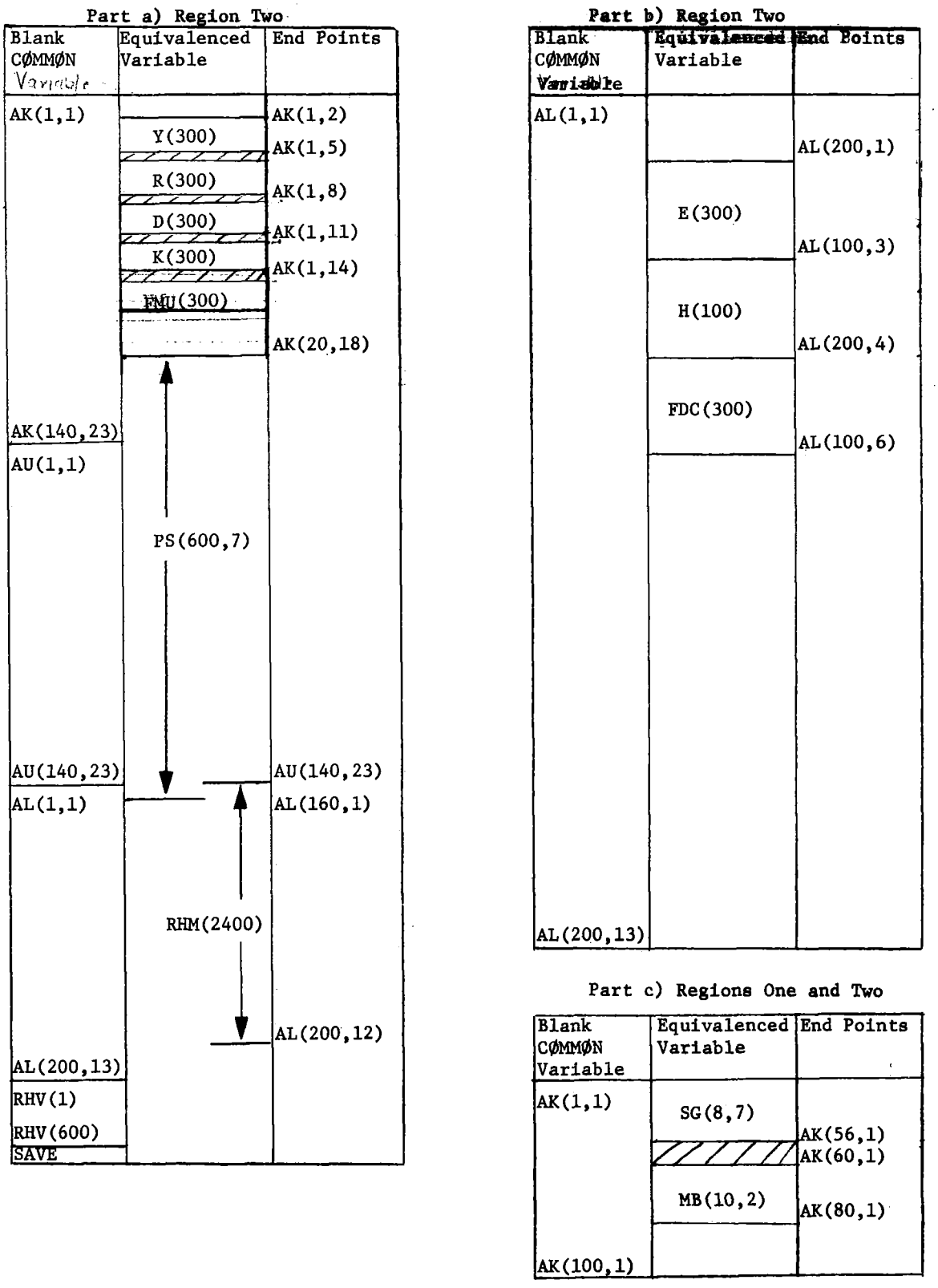


Figure 2.13 Region One and Two. Definition of Equivalenced Variables

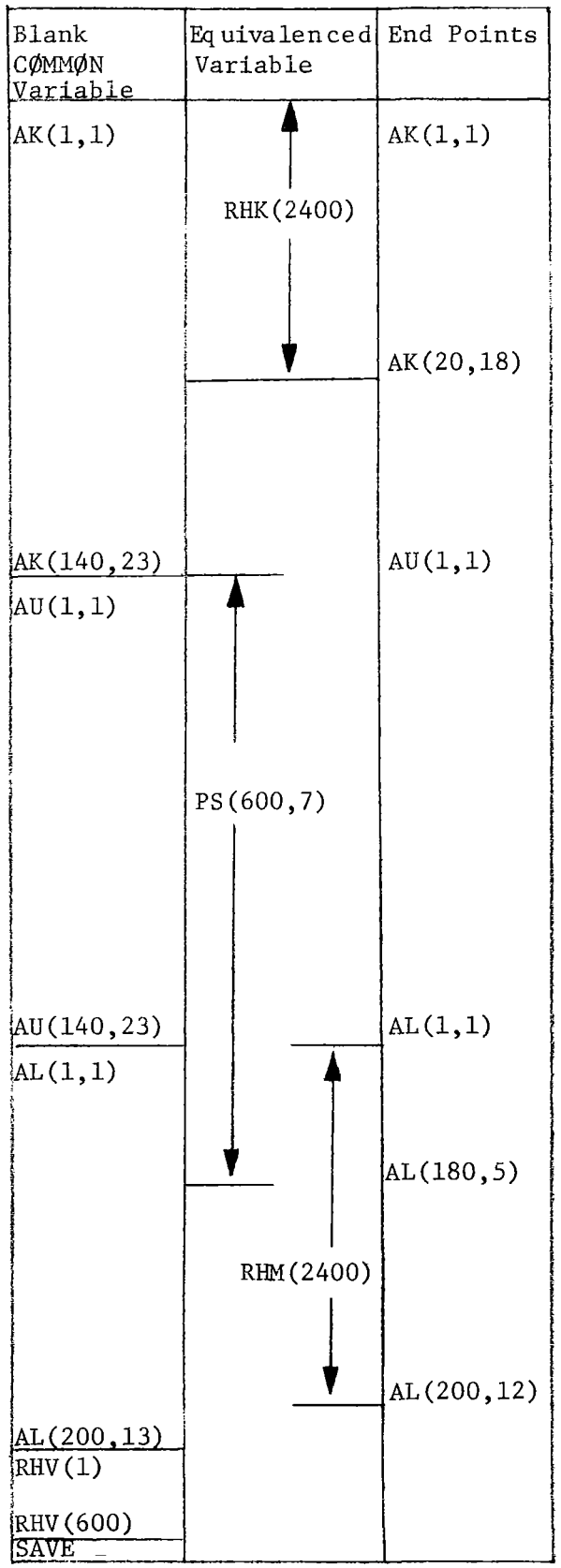


Figure 2.14 Region Three. Definition of Equivalenced Variables

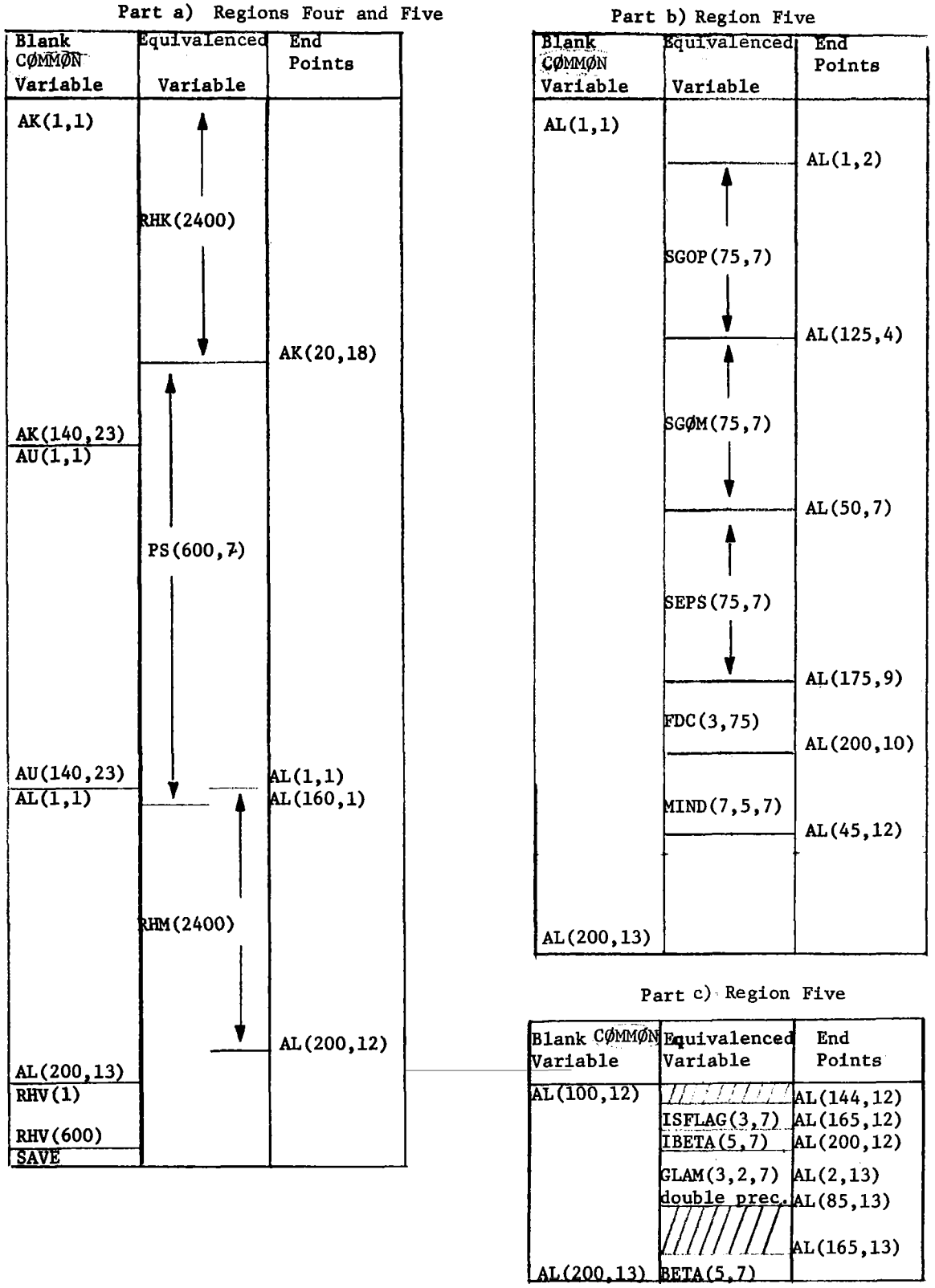


Figure 2.15 Region Four and Five. Definition of Equivalenced Variables

Part a)

Blank COMMON Variable	Equivalenced Variable	End Points
AK(1,1)	RHK(2400)	
		AK(20,18)
AK(140,23)		
AU(1,1)	PS(600,7)	
AU(140,23)		
AL(1,1)		AL(160,1)

Part b)

Blank COMMON Variable	Equivalenced Variable	End Points
AL(1,1)		
		AL(200,1)
		AL(1,2)
	EØM(75.7)	
		AL(125,4)
	ENT(75,7)	
		AL(50,7)
	EMPT(75,7)	
		AL(175,9)
	EMT(75,7)	
		AL(200,12)
	SP(91)	
		AL(91,13)
AL(200,13)	ISFLAG(3,7)	AL(112,13)

Part c)

Blank COMMON Variable	Equivalenced Variable	End Point	Equivalenced Variable	End Points
RHV(1)	PB(75,5)		MIND(7,5,7)	RHV(245)
		RHV(375)	FDC(3,75)	
				RHV(470)
RHV(600)			TP (91)	RHV(561)

Figure 2.16 Region Six. Definition of Equivalenced Variables

a) Main monitor

NAME	VARIABLE	DEFINITION OF VARIABLE
CØMAA	ICHECK	Flag for intermediate printout
CØMBB	CCBETA	Contains the value of β for which convergence is assumed.
	IIMITE	Contains the maximum number of harmonic loops the program will perform for each load level.
CØMCC	CØNFAC	Contains the convergence factor.

b) Region one

There are no named CØMMØN blocks used exclusively in region one.

c) Region two

There are no named CØMMØN blocks used exclusively in region two.

d) Region three

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM31		If index of point under consideration is "I"
	AC(8,8)	"A" coefficients for point "I"
	AD(8,8)	"A" coefficients for point "I+1"
CØM32		
	SINE	Sin(ϕ) for current segment
	CØSI	Cos(ϕ) for current segment
	M	Current harmonic value

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM33		
	IJ	Index of point under consideration
	MS	Index of starting point of current segment
	MF	Index of last point of current segment.
	IND	The row number of the "K" matrix for the current record.
	IJK	The index of the segment under consideration
	IJH	The index of the harmonic under consideration
	IDIAG	The row number of the main diagonal of the "K" matrix = 12
CØM34		
	LØØP	Flag which indicates whether or not the modified "A" coefficients may be used. = 0 no = 1 yes
CØM35		If the current point index is "I"
	R1	Radius for point "I"
	D1	Extensional stiffness for point "I"
	K1	Bending stiffness for point "I"
	FDC1	Central difference for point "I"
	FM1	Poisson's ratio for point "I"
	R2	Radius for point "I+1"
	D2	Extensional stiffness for point "I+1"
	K2	Bending stiffness for point "I+1"
	FDC2	Central difference for point "I+1"
	FM2	Poisson's ratio for point "I+1"

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM36	GØTH(300)	Circumferential rotation (ω_θ) for all points and harmonic = 2M
	GØPH(300)	Meridional rotation (ω_ϕ) for all points and harmonic = 2M
	GNPT(300)	In plane shear force ($\overline{N}_{\phi\theta}$) for all points and harmonic = 2M.
	GNTH(300)	Circumferential force (N_θ) for all points and harmonic = 2M
	SIFØR	Flag governing use of above "UPDATE" variables = 0.0 Do not use them = 1.0 Do use them
CØM37		If index of point under consideration is "I"
	ZBR(2)	Normal loading ($\overline{Z}$) for points "I" and "I+1"

e) Region four

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM41		
	KRMP1	= One plus the number of columns to the left of the main diagonal of the "K" matrix = 12
	KRMP2	= 13
	MRT	= 1
	KBL	= Bandwidth of the "K" matrix = 23
	IPTBL(7)	= Set by MABTX, MABLX, and MABBX

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM42		
	AB(23)	Locations where each row of "K" is placed as input to MABTX
	U(23)	Locations where each row of "U" is placed by MABTX
	ST(12)	Locations where the matrix scale factors for one harmonic are placed
	AL1(13)	Locations where each row of "L" is placed by MABTX
	R(1)	Location where each right hand vector element is placed by BSUBX
	X(1)	Location where each solution value is put by MABBX
	C(1)	Location where each "P" element is put by MABLX
CØM43		
	DTM	Scaled double precision determinant of the "K" matrix
	DTM1	The scaled single precision or depressed determinant of the "K" matrix
CØM44		
	CRT(12,1)	Working storage used by MABLX
	ALT(13)	Double precision block of working storage used by MABTX
	CT(12)	Double precision block of working storage used by MABTX
CØM45		
	INTF2	Internal flag number two
CØM49		
	IØPT5	Output option number five

f) Region five

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM51		
	IJK	Index of segment under consideration
	IJH	Index of harmonic under consideration
	IJ	Index of point under consideration
	MS	Index of starting point of this segment
	MF	Index of ending point of this segment
CØM52		
	SINE	Double precision value of sine (PHI) for current segment
	CØSI	Double precision value of cosine (PHI) for current segment
	HM	Double precision value of current harmonic
	M	Single precision value of current harmonic
	NØNE	Index for point "I" and "I+1"
CØM53	(All variables are in double precision)	
	D(2)	Extensional stiffness for points "I" and "I+1"
	BK(2)	Bending stiffness for points "I" and "I+1"
	R(2)	Radius for points "I" and "I+1"
	FM(2)	Poisson's ratio "I" and "I+1"
	DS(2)	Central difference for points "I" and "I+1"
	XBR(2)	Circumferential loading for points "I" and "I+1"
	YBR(2)	Meridional loading for points "I" and "I+1"

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM54	(All variables are in double precision)	
	RSTR(8)	Eight R* values for point "I"
	ZBR(7,2)	Normal loading for all harmonics, points "I" and "I+1"
	GØP(7,2)	Meridional rotation for all harmonics, points "I" and "I+1"
	GØM(7,2)	Normal rotation for all harmonics, points "I" and "I+1"
	GNT(7,2)	Circumferential force for all harmonics, points "I" and "I+1"
	GNPT(7,2)	Shear force for all harmonics, points "I" and "I+1"
	FLAM(9,2)	Lambda values for points "I" and "I+1"
	EPS(7,2)	Strain for all harmonics, points "I" and "I+1"
CØM55	(Both variables are in double precision)	
	GMT(2)	Circumferential moment for points "I" and "I+1"
	GMPT(2)	Shear moment for points "I" and "I+1"
CØM56	(Variable is in double precision)	
	X(8,2,7)	Values of eight unknowns for points "I" and "I+1" and for all harmonics
CØM57		
	ERS	e_r^s for this segment and harmonic
	EYS	e_y^s for this segment and harmonic
	R1	Radius at last point of segment (R_n)
	RBB	Support radius for this segment and harmonic divided by "R1" i.e., R_s/R_n

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM58	(All variables are in double precision)	
	A(7)	These four storage vectors are used to input the forces and rotations to the summation subroutine
	B(7)	
	C(7)	
	DZ(7)	
CØM59		
	IND	Index for new solution vector for one segment
	INDK	Index for new solution vector for entire shell

g) Region six

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM61	IJK	Index of current segment
	IJH	Index of current harmonic
	IJ	Index of current point
	MS	Index of starting point of this segment
	MF	Index of ending point of this segment
CØM62		
	R	Radius for this point
	D	Extensional stiffness for this point
	CK	Bending stiffness for this point
	FM	Poisson's ratio for this point
	SD	S-mesh value for this point
	ARC	Arc length for this point
	HT	Thickness for this point

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM63		
	HNT(7)	Circumferential force (N_θ) for all harmonics at current point
	HMPT(7)	Shear moment ($M_{\phi\theta}$) for all harmonics at current point
	HØP(7)	Meridional rotation (ω_ϕ) for all harmonics at current point
	HØM(7)	Normal rotation (ω_M) for all harmonics at current point
	HMT(7)	Circumferential moment (M_θ) for all harmonics at current point
CØM64		
	X(8,7:0	Eight unknowns for all harmonics: (u, v, w, ω_θ, $\overline{N}_{\phi\theta}$, N_ϕ, $\overline{Q}_\phi$, M_ϕ)
CØM65		
	A(7)	These two arrays are used to input information to the summation subroutine SUNNX
	B(7)	
CØM66		
	GLAM(3,7)	Storage for $\lambda^{(2)}$, $\lambda^{(3)}$, and $\lambda^{(4)}$ for all harmonics at current point
CØM67		
	SINE	Sin (ϕ) for this segment
	CØSI	Cos (ϕ) for this segment
	HM	Floating point value of current harmonic
	M	Fixed point value of current harmonic

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM68		For the point under consideration:
	DELR(7)	Radial displacement for all harmonics (δ_r)
	DELY(7)	Axial displacement for all harmonics (δ_y)
	ANR(7)	Radial force for all harmonics (N_r)
	ANY(7)	Axial force for all harmonics (N_y)
	AMP(7)	Meridional bending moment for all harmonics (M_ϕ)
	AMT(7)	Circumferential bending moment for all harmonics (M_θ)
CØM69		Controls flow of program
	KST	= IJH. Calculations for "IJHth" harmonic
		= KS. Calculations for combined harmonics
	NSØC	= 1 Separate harmonic calculations
		= 2 Combined harmonic calculations
	PTEM(20)	Printing buffer
CØM6A		
	STHE(7)	sin(Mxθ) for each harmonic
	CTHE(7)	cos(Mxθ) for each harmonic
CØM6B		
	IØPT6	Output option number six
	IØPT7	Output option number seven
	IØPT8	Output option number eight
	IØPT9	Output option number nine
	IØPT10	Output option number ten
	IØPT11	Output option number eleven
	IØPT12	Output option number twelve
	IØPT13	Output option number thirteen
	IØPT14	Output option number fourteen

NAME	VARIABLE	DEFINITION OF VARIABLE
CØM6C		
	NFLAG	Controls plotting = 0 no plotting = 1 plot only force vs. S for values of theta = 2 plot only force vs. theta at several points = 3 plot both 1 and 2
	MFLAG	Controls use of sin (θ) or cos (θ) in plot summations = 1 Use sin (M*θ) = 2 Use cos (M*θ)
	MMFLAG	Contains index of force being printed = 1 Circumferential force (N_θ) = 2 Circumferential bending moment (M_θ) = 3 In plane shear force ($\bar{N}_{\phi\theta}$) = 4 Meridional force (N_ϕ) = 5 Meridional bending moment (M_ϕ)
	TPLTIM	Contains total plotting time for this load level
CØM6D		
	THET	Floating point value of theta
CØM6E		
	NPLØT	Contains number of plots made for this load level
CØM6F		
	SIGMAX	Maximum value of effective stress for segment
	SIGTHE	Value of theta at maximum stress
	ISIGPT	Point number of maximum stress

h) Region seven

There are no named CØMMØN blocks used exclusively in region seven

2.7.6 Core Layout.

The core use by the program for each of the overlay links is shown in Figure 2.17. The starting points given are for the TRW Systems transcription mode using the 13JB systems tape.

2.7.7 Subroutine Descriptions.

This section contains a brief description of the subroutines in each region of the program.

1. Main Monitor

MONIX — Calls each of the regions depending on the status of the overlay flag KKKKK.

FDICX — Calculate the finite difference coefficients for each point in one segment of a S-mesh. The S-mesh vector and the starting and ending indices of the segment under consideration must be input to FDICX.

GETMX — Given a list of harmonics and the number of harmonics in the list, GETMX determines and saves for each harmonic M the indices of the harmonics such that in the following three types of harmonic summations the terms of the summation are not trivially equal to zero (i.e., the subscripts of each factor in a given term are in the list of harmonics).

1. $\sum_{\ell=1}^{\infty} A_\ell \, B_{M+\ell}$

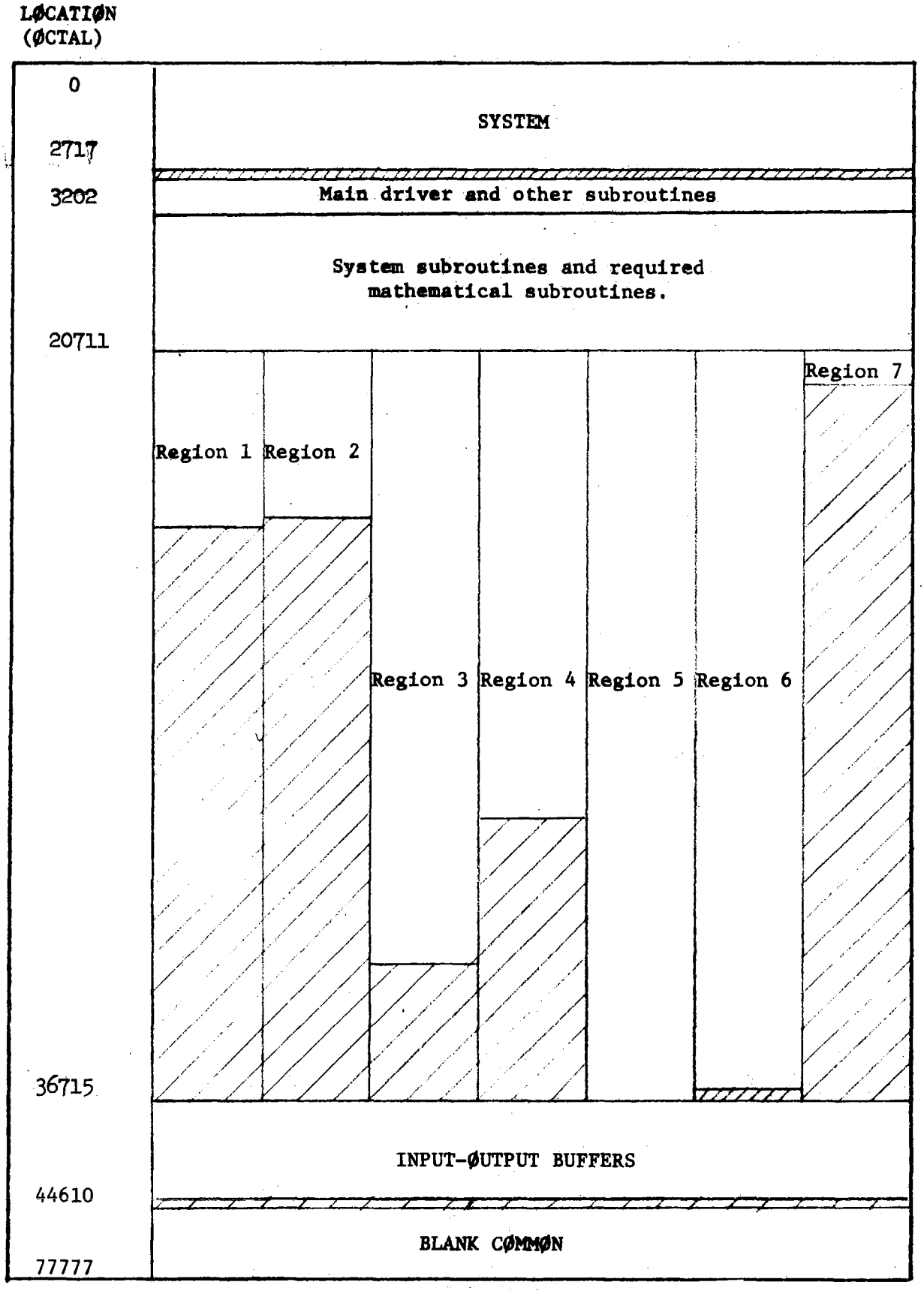


Figure 2.17 Core Layout

2. $\sum_{\ell=1}^{M-1} A_\ell \, B_{M-\ell}$

3. $\sum_{\ell=1}^{\infty} A_\ell \, B_\ell$

The arrays ISFLAG and MIND are generated. They are defined by the following:

ISFLAG(1,M) = number of harmonics greater than zero for harmonic M

(2,M) = number of pairs of harmonics such that 'L' and 'M + L' exist in the harmonic list for harmonic M

(3,M) = number of pairs of harmonics such that 'L' and 'M - L' exist in the harmonic list for harmonic M

MIND(I,1,M) = 'M + L' index for I^{th} 'L' and 'M + L' pair

(I,2,M) = 'L' index for I^{th} 'L' and 'M + L' pair

(I,3,M) = 'L' index for I^{th} 'L' and 'M - L' pair

(I,4,M) = 'M - L' index for I^{th} 'L' and 'M - L' pair

(I,5,M) = number of harmonics in list less than M for I^{th} harmonic

UN50 Contains the file definitions for tape 50

PADR Required by the plotting subroutine CCP

GEØØ Required by the plotting subroutine CCP

2. Region one

MØNIX Reads, prints and makes consistency checks on most of the input data.

BCØNX Reads and prints the boundary condition input data. Consistency and uniqueness checks are also made on the data.

PDINX Reads and prints the segment plotting flags, the individual point plotting flags, and the load plotting flags. See input data description for definitions of these flags.

3. Region Two

MØN2X Monitors the geometry calculations of the shell and optionally prints them. The increments due to the input axial and radial loadings are added to the circumferential and normal loading end points.

GEØMX For each segment GEØMX calculates the sine (ϕ) and the cosine (ϕ), the radius (R), and the vertical distance (Y). GEØMX also calls the subroutine MESHX.

MESHX For each segment MESHX generates the S-mesh.

EHMUX Given the initial and final values of a linear function, EHMUX calculates the values of that function at each point in the S-mesh. This subroutine calculates Young's modulus (E), the thickness (H), and Poisson's ratio (μ) for each segment.

DANKX Given Young's modulus (E), Poisson's ratio (μ), and thickness (H) at each point of an S-mesh, DANKX calculates the extensional (D) and bending (K) stiffness at each point in the S-mesh.

NRPRX For a restart case NRPRX calculates the number of rows in each record of the "U" and "L" matrices on the "L + U" tape.

4. Region Three

MØN3X Determines the harmonic values for which to build up the "K" matrix and calculates for an update case the special iteration forces for all harmonics but the zero harmonic.

HARMX Controls the construction of the "K" matrix for the given harmonic. HARMX saves the matrix on tape, optionally prints the matrix, and saves the right hand vector for the first special iteration.

MISCX For the point under consideration:

1) Calculates the values of required physical characteristics of the segment.
2) Transfers these values for "I+1"th storage arrays to "I"th storage arrays.

ACADX Controls the calculation of the "A" coefficients and the modified "A" coefficients for the "I"th point and the "I+1"th point.

ACØFX Calculates the "A" coefficients for a given point.

MACØX Calculates the modified "A" coefficients for a given point.

GAMMX Builds the leading and trailing boundary condition equations.

BETAX Builds the leading and trailing discontinuity equations.

KCØFX Calculates the "k" coefficients used in the discontinuity equations.

EQUMX Calculates the equilibrium equations for the "I"th point.

BRHVX Builds the right hand vector for the first special iteration.

5. Region Four

MØN4X Monitors the solution of the equations. MØN4X calls each of the subroutines LANUX, PELRX and BSUBX. For special iterations MØN4X calls LANUX and BSUBX. At the beginning of the ordinary iterations, MØN4X calls LANUX for each harmonic, sets up the "L + U" tape in the proper format as shown in Figure 2.8, and prints the matrix scale factors. For the ordinary iterations MØN4X calls PELRX then BSUBX.

PELRX Interacts with the almost band matrix multiplication subroutine MABLX for each harmonic. Used only for ordinary iterations, PELRX inputs the transformation matrix "L" and the right hand vector "R" to MABLX and obtains the vector "P", which is saved on top of "R". "L" is read from the "L+U" tape.

BSUBX Interacts with the almost band matrix back-substitution subroutine MABBX for each harmonic. BSUBX inputs the upper triangular matrix "U" and the vector "P" to MABBX and obtains the solution vector "X", which is stored on top of "P". The matrix "U" is read from a scratch tape for special iterations and read from the "L+U" tape for ordinary iterations.

PRNXX Prints the incremental solution vector if solution diverges.

PRMYX Prints intermediate results in program checkout. This subroutine is not entered in normal execution of a problem.

MABTX Triangularizes a band matrix.

MABLX Performs a matrix multiplication for a band matrix.

MABBX Performs a back-substitution for a band matrix.

RDCXX Used by MABTX.

6. Region Five

MØN5X Reads the prior solution tape for each segment, CALL's TCCRX to calculate the convergence criterion data, adds the incremental solution to the prior solution, CALL's CNRHX to build the new right hand vector, tests for convergence, and increments the loading after each convergence.

TCCRX Calculates the convergence criterion data for each harmonic. The five maximum values in a shell for each harmonic are saved.

CNRHX Monitors the calculation of the new right hand vector at each point for the given segment. The subroutines called are ØMEGX, SDATX, PVALX, BVECX or DVECX, and RANPX.

ØMEGX For the segment under consideration, ØMEGX calculates the meridional rotation (ω_ϕ), the normal rotation (ω) and the strain (ε) at each point. ØMEGX also calls the subroutine FDICX to calculate the finite difference coefficients for each point of the segment.

SDATX Performs three functions:

1. Calculates the necessary physical characteristics of the segment at this point.
2. Calculates the circumferential and meridional loading at this point for the harmonic under consideration, as well as the normal loading at this point for all harmonics.
3. For all harmonics, transfers to a named CØMMØN block the eight unknowns from previous solutions for this point. Additionally, SDATX transfers the circumferential and meridional rotations and the strain which were calculated segment-wise from the segment storage arrays to the named CØMMØN blocks for this point.

SDATX is entered once for each point.

PVALX Calls the subroutine LAMBX to calculate the LAMBDA values, calculates the circumferential and shear forces for all harmonics, and calculates the shear moment for the current harmonic. All values are calculated in double precision.

LAMBX Calculates the LAMBDA values at each point for the following situations:

1. LFLAG = 1: Calculates LAMBDA(3) and LAMBDA(4) for all harmonics and stores the values in the GLAM array.
2. LFLAG = 2: Calculates LAMBDA(2) for all harmonics and stores the values in the GLAM array.
3. LFLAG = 3: Calculates LAMBDA(I), I = 1,5,6,7,8, and 9 for the harmonic under consideration and stores the values in the FLAM array.

LAMBX usually calls the subroutine SUMMX which performs the summations for each LAMBDA value. The input to the summation subroutine for each LAMBDA is described in the input buffer definitions in Figure 2.18.

SUMMX Performs one of the four following types of summations depending on the input flags.

SUMMATIONS

1. IABCD = 1

$$\lambda_M^{(I)} = [AxB]_M$$

$$= A_o B_M + (IFLAG)(A_M B_o)$$

$$+ \frac{1}{2} \sum_{\ell=1}^{\infty} [A_\ell B_{(M+\ell)} \bar{\oplus} A_{(M+\ell)} B_\ell]$$

$$+ \frac{1}{4} \sum_{\ell=1}^{M-1} [A_\ell B_{(M-\ell)} + A_{(M-\ell)} B_{(\ell)}]$$

If IFLAG = 1, signs circled are used.
= 0, signs circled aren't used

LAMBDA NUMBER	HARMONIC VALUE	IFLAG VALUE	IABCD	INPUT BUFFERS A	B	C	D	COMMENT
1	M=0 M≠0	0 0	- 2	- $N_{\phi\theta}$	- ω_{θ}	- N_{θ}	- ω_{ϕ}	See d. -
2	M=0 M≠0	0 0	- 1	- $N_{\phi}+N_{\theta}$	- ω	- -	- -	See d.
3	M=0 M≠0	1 0	4 3	ω_{ϕ} ω_{ϕ}	- ω	ω -	- -	- -
4	M=0 M≠0	- 0	- 1	- ω_{θ}	- ω_{ϕ}	- -	- -	See d. -
5	M=0 M≠0	0 1	4 2	ω_{θ} ω_{θ}	N_{ϕ} N_{ϕ}	$N_{\phi\theta}$ $N_{\phi\theta}$	ω_{ϕ} ω_{ϕ}	See a. -
6	M=0 M≠0	1 1	4 3	ω_{θ} ω_{θ}	 ω	ω -	 -	See b. See e.
7	M=0 M≠0	- 1	- 1	- $\bar{Z}$	- ω_{θ}	- -	- -	See c. -
8	M=0 M≠0	- 0	- 1	- $\bar{Z}$	- ω_{ϕ}	- -	- -	See d. -
9	M=0 M≠0	- 1	- 1	$\bar{Z}$ $\bar{Z}$	- ε	- -	- -	See c. -

a. Add $N_{\phi_0} \times \omega_{\theta_0}$ to summation

b. Add $(\omega_{\theta_0})^2$ to summation

c. LAMBDA value calculated within LAMBX subroutine

d. LAMBDA value = 0

e. Add $2 \times \omega_{\theta_0} \times \omega_{\theta_M}$ to summation

Figure 2.18 Definition of Input Buffer Values and Flag Values Set for the Summation Subroutine

2. IABCD = 2

$$\lambda_M^{(I)} = [AB + CD]_M$$

$$= B_o A_M + (IFLAG - 1)(C_o D_M) + IFLAG(A_o B_M)$$

$$+ \frac{1}{2} \sum_{\ell=1}^{\infty} [B_\ell A_{(M+\ell)} + C_\ell D_{(M+\ell)}$$

$$\bar{\oplus} (B_{(M+\ell)} A_\ell + C_{(M+\ell)} D_\ell)]$$

$$+ \frac{1}{4} \sum_{\ell=1}^{M-1} [B_\ell A_{(M-\ell)} \overset{+}{\theta} C_\ell D_{(M-\ell)} + B_{(M-\ell)} A_\ell$$

$$\overset{+}{\theta} C_{(M-\ell)} D_\ell]$$

If IFLAG = 1, signs circled are used.
= 0, signs circled aren't used.

3. IABCD = 3

$$\lambda_M^{(I)} = [A^2 + B^2]_M$$

$$= \sum_{\ell=1}^{\infty} [A_\ell A_{(M+\ell)} + B_\ell B_{(M+\ell)}]$$

$$\bar{\oplus} \frac{1}{2} \sum_{\ell=1}^{M-1} [A_\ell A_{(M-\ell)} \overset{+}{\theta} B_\ell B_{(M-\ell)}]$$

If IFLAG = 1, signs circled are used.
= 0, signs circled aren't used.

4. IABCD = 4

$$\lambda_M^{(I)} = [AB + CD]_M$$

$$= \frac{1}{2} \sum_{\ell=1}^{\infty} [A_\ell B_\ell + C_\ell C_\ell]$$

If IFLAG = 0, A,B,C, and D are distinct
= 1, set B = A and D = C

BVECX Calculates the leading and trailing boundary condition values for the first and last segments of the shell. In addition, for the last segment BVECX transfers the right hand vector values from the one segment storage vector RHV to the entire shell storage vector RHK.

DVECX Calculates the leading and trailing discontinuity equation values. Subroutine is entered twice at each junction as some terms in both trailing and leading values require the unknown values at the last point of one segment and the first point of the following segment. After the leading values have been calculated, the right hand vector values are transferred from the one segment storage array RHV to the entire shell storage array RHK.

KCØGX Performs the exact same function as region three subroutine KCØFX.

RANPX For each of the points in a segment, RANPX calculates the residual (R*) values and forms the new right hand vector. Note that RANPX must calculate the index position of the named CØMMØN block variables for both the current and next point.

7. Region Six

MØN6X Monitors region six. The shell is considered segment-wise for all harmonics.

FMRØX Calculates the normal rotation (ω), the circumferential force (N_θ) and moment (M_θ), and the shear moment ($M_{\phi\theta}$) at all points for all harmonics for the given segment.

SDAVX Performs three functions for the point under consideration:

1. Calculates the required physical characteristics.
2. Transfers the eight unknowns for all harmonics from a segment storage array to a point storage array.
3. For all harmonics, transfers the normal rotation (ω), the circumferential force (N_θ) and moment (M_θ), and the shear moment ($M_{\phi\theta}$) from segment storage arrays to point storage arrays.

LANBX Calculates $\lambda^{(2)}$, $\lambda^{(3)}$, and $\lambda^{(4)}$ for all harmonics at the given point.

SUNNX Performs the type "A" summation described in the region five subroutine "SUMMX".

STRTX Prints the heading at the top of each page and the first line at each point including the point number, segment number, etc.

DISPX Calculates and prints the displacements and rotations for the point under consideration.

FORCX Calculates and optionally prints the forces and stresses for the point under consideration.

SUFPX Calculates the results of a given force for the plotting options.

IBCDFR Sets a floating point integer of three digits or less to left-justified hollerith form.

PLOTX A subroutine which CALL'S SCAL and CCP to scale end plot curves on linear grids. Detailed descriptions of SCAL and CCP have been included to aid installation plotting subroutine implementation.

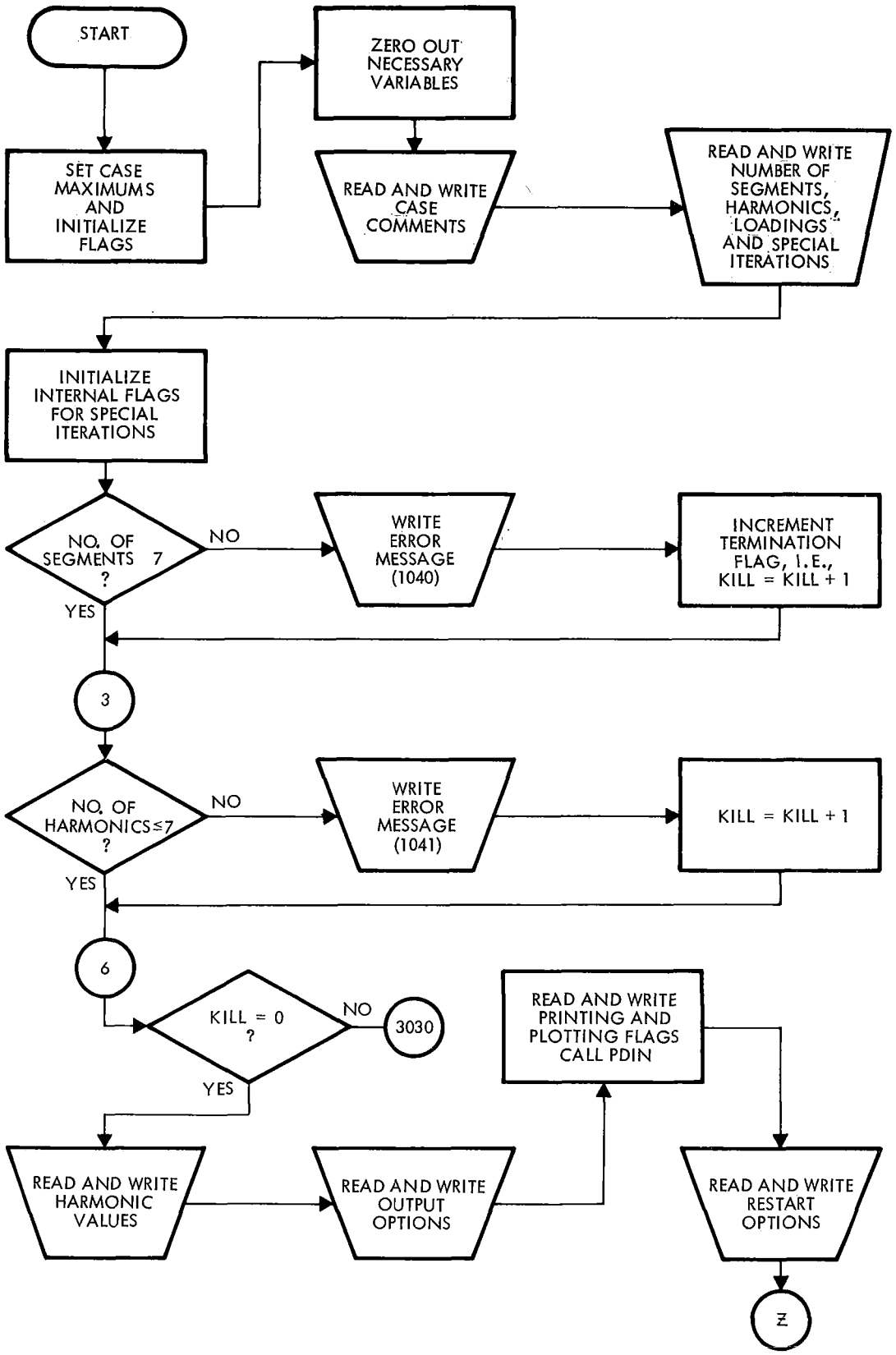


Figure 2.19. Subroutine MON1X

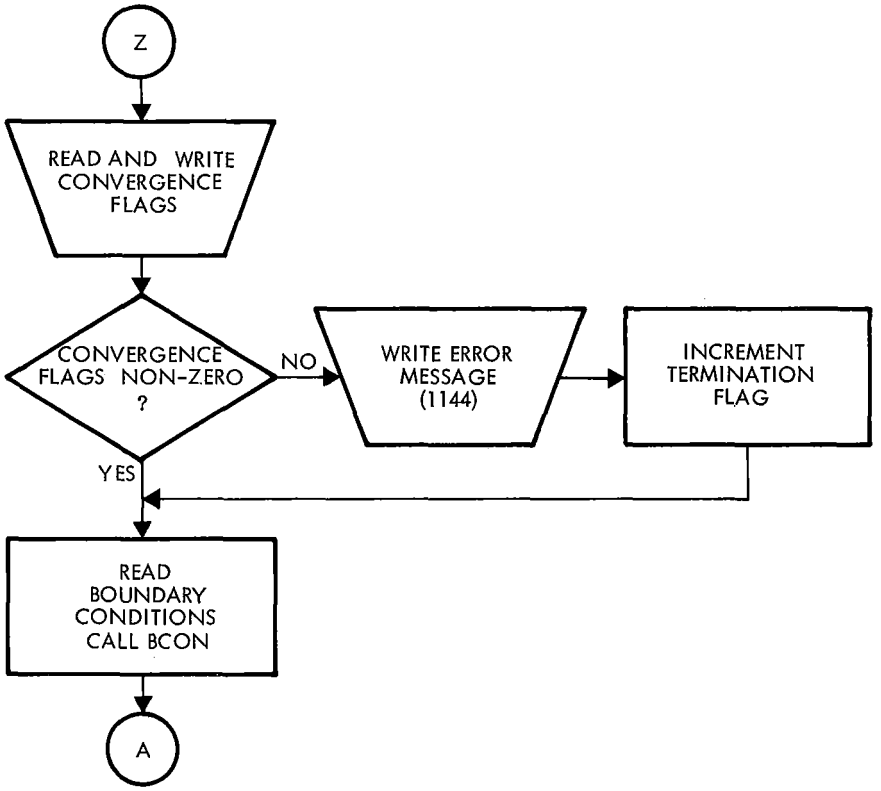


Figure 2.19. Subroutine MON1X (Continued)

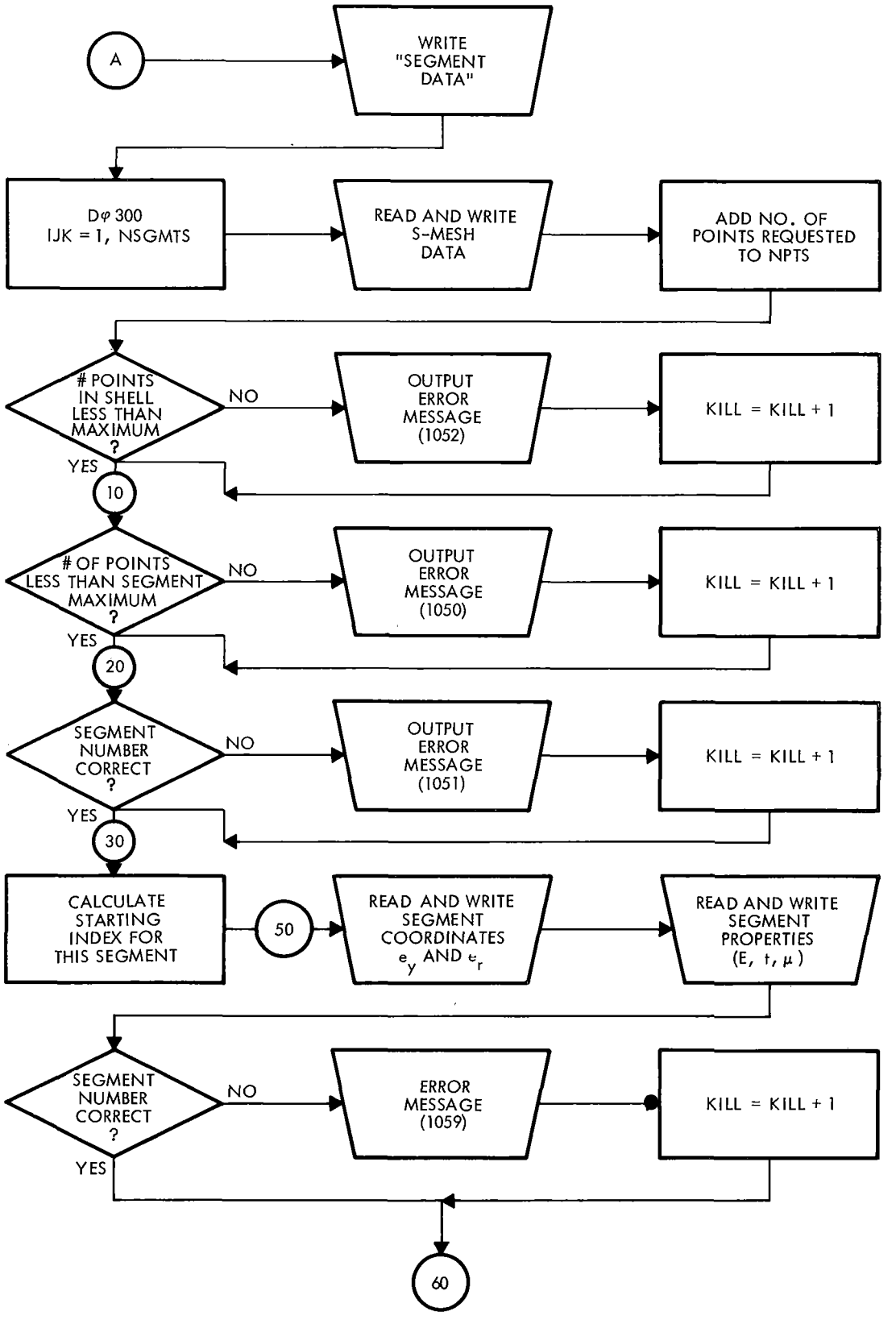


Figure 2.19. Subroutine MON1X (Continued)

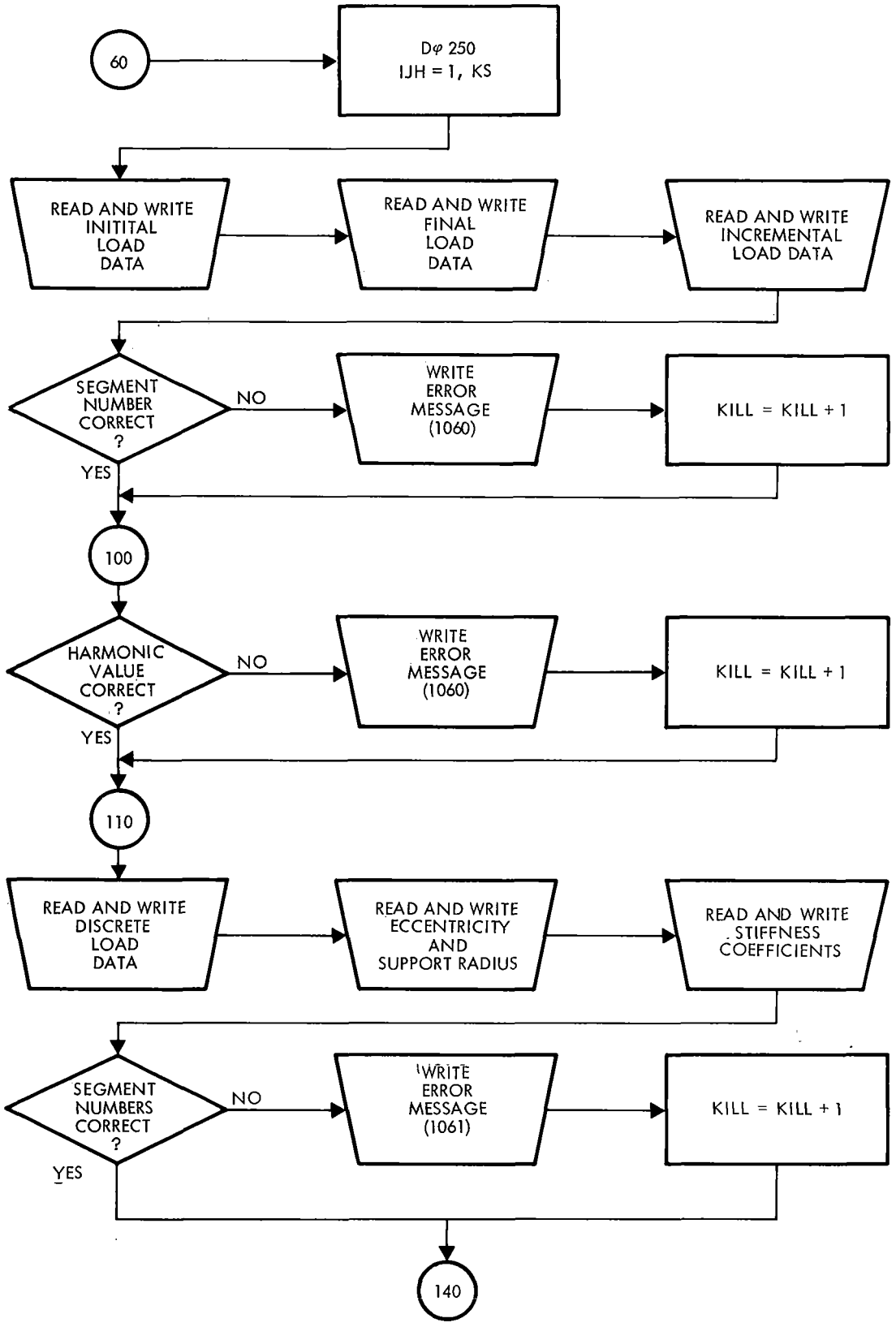


Figure 2.19. Subroutine MON1X (Continued)

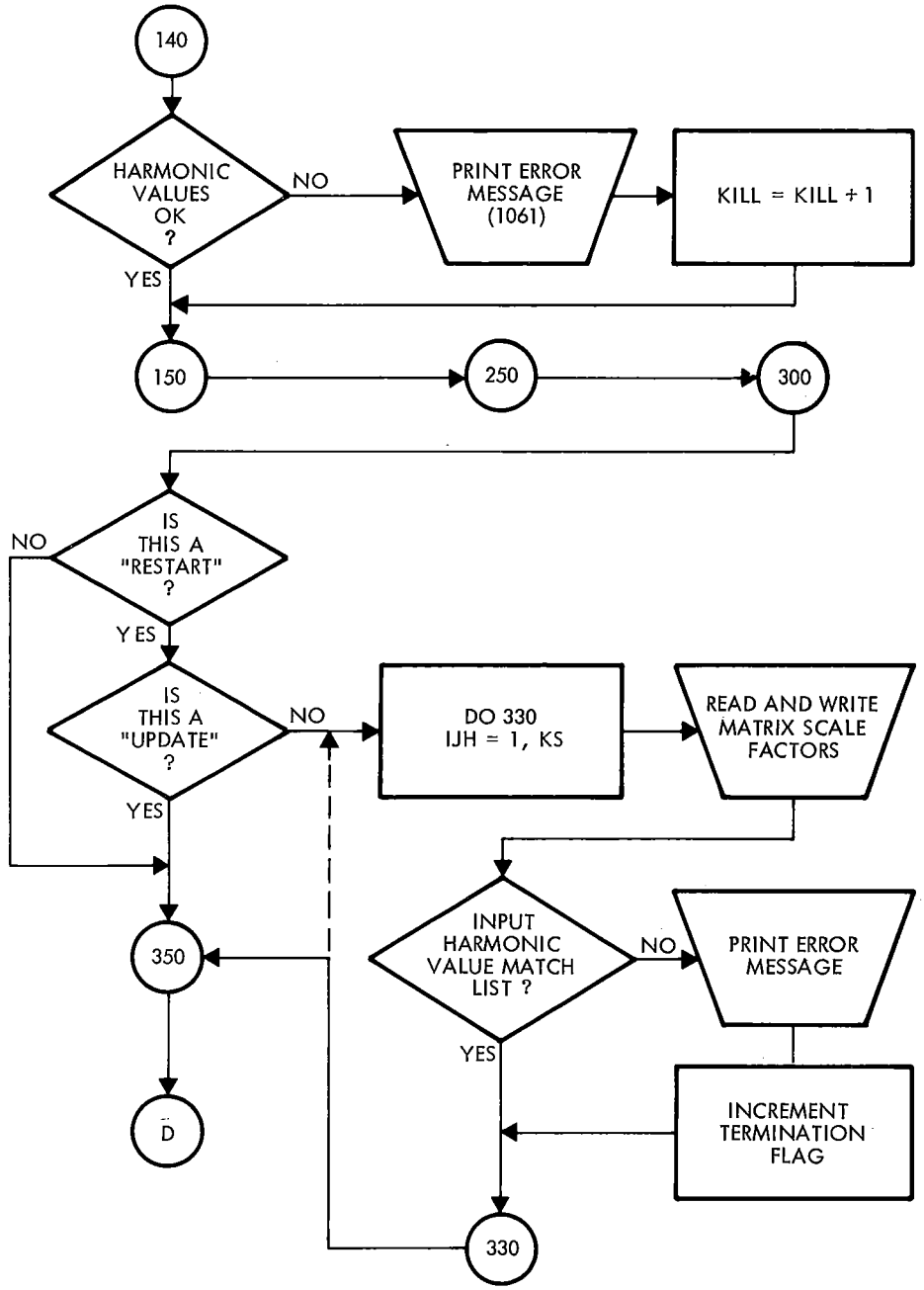


Figure 2.19. Subroutine MON1X (Continued)

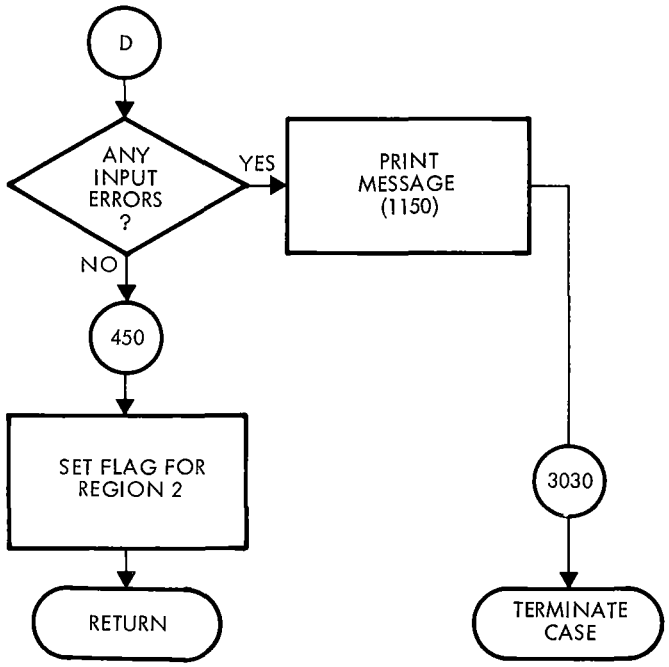


Figure 2.19. Subroutine MON1X (Continued)

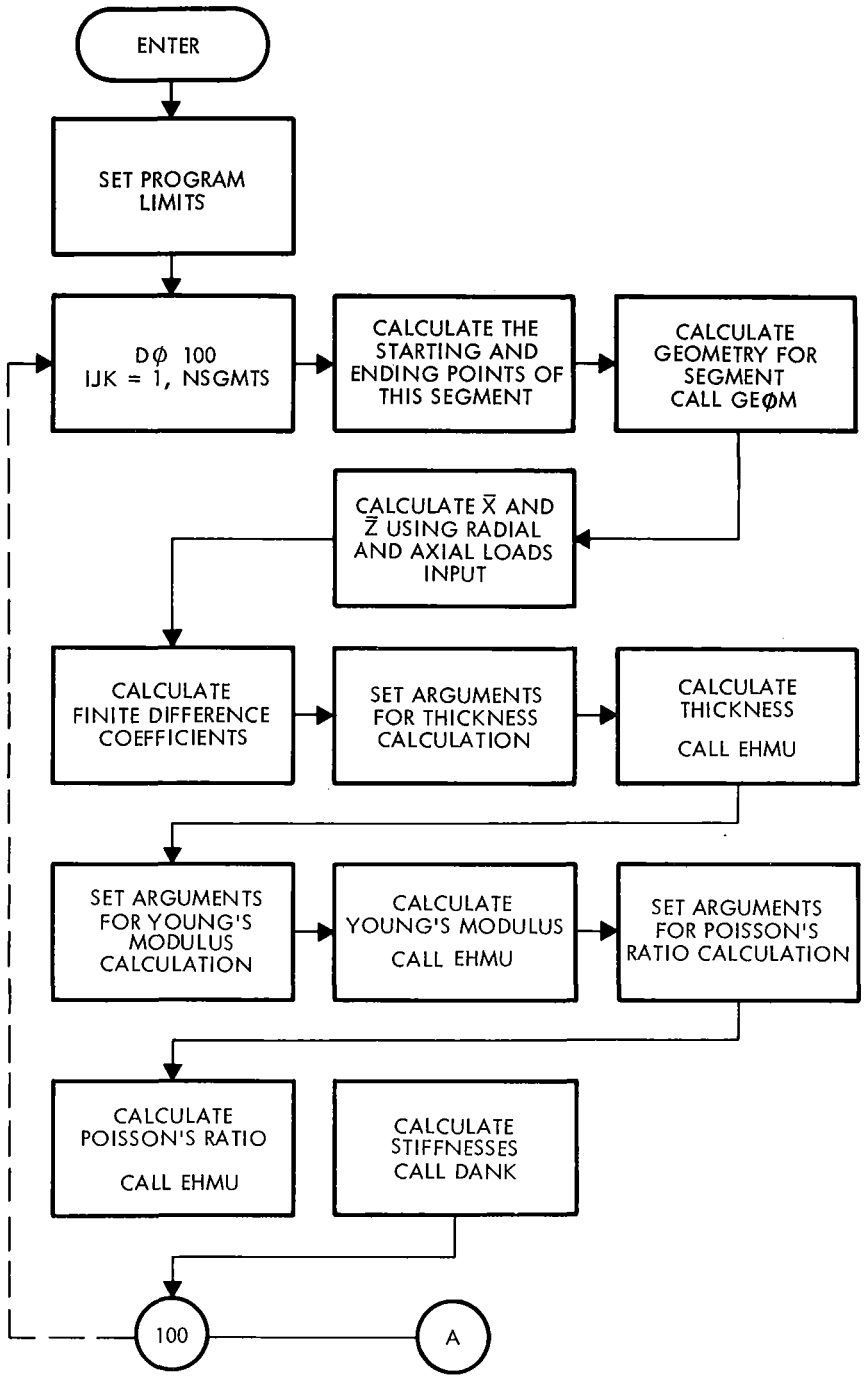


Figure 2.20. Subroutine MON2X

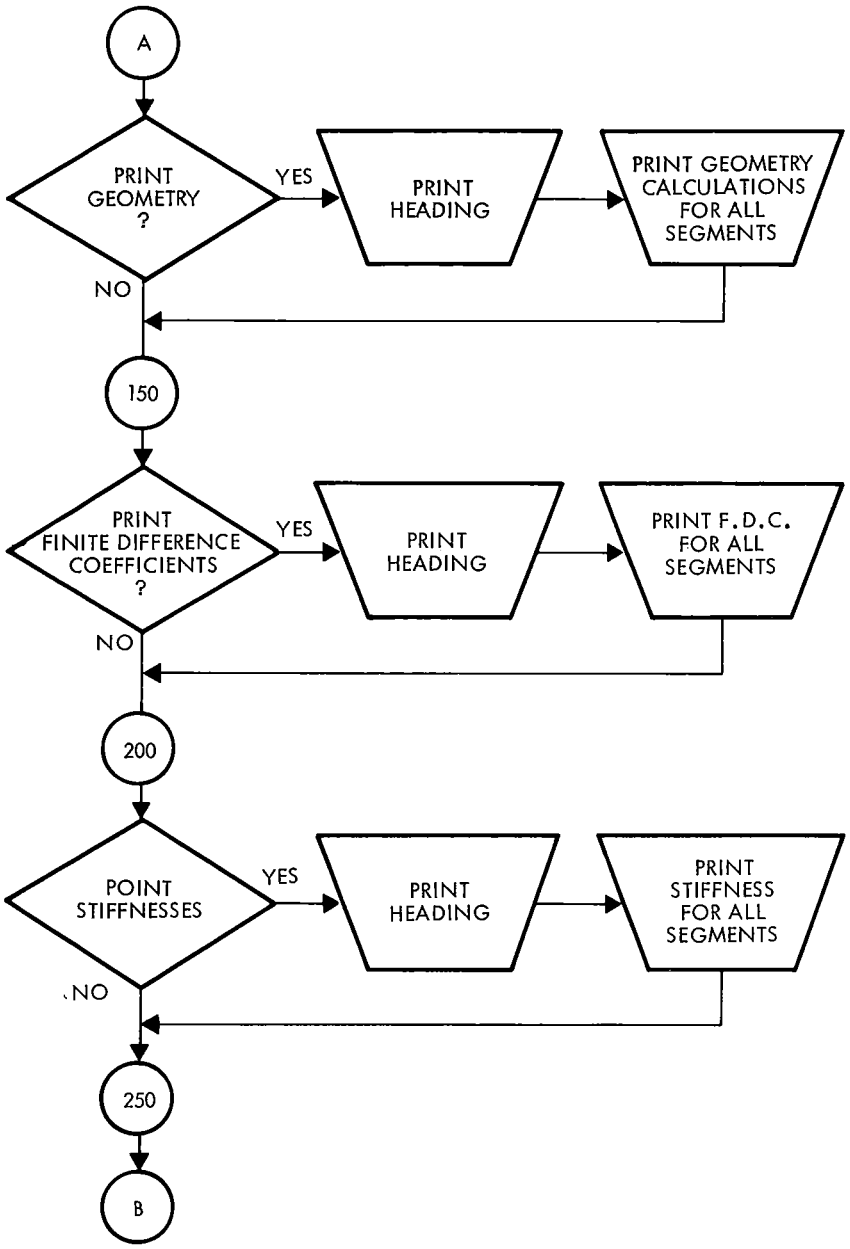


Figure 2.20. Subroutine MON2X (Continued)

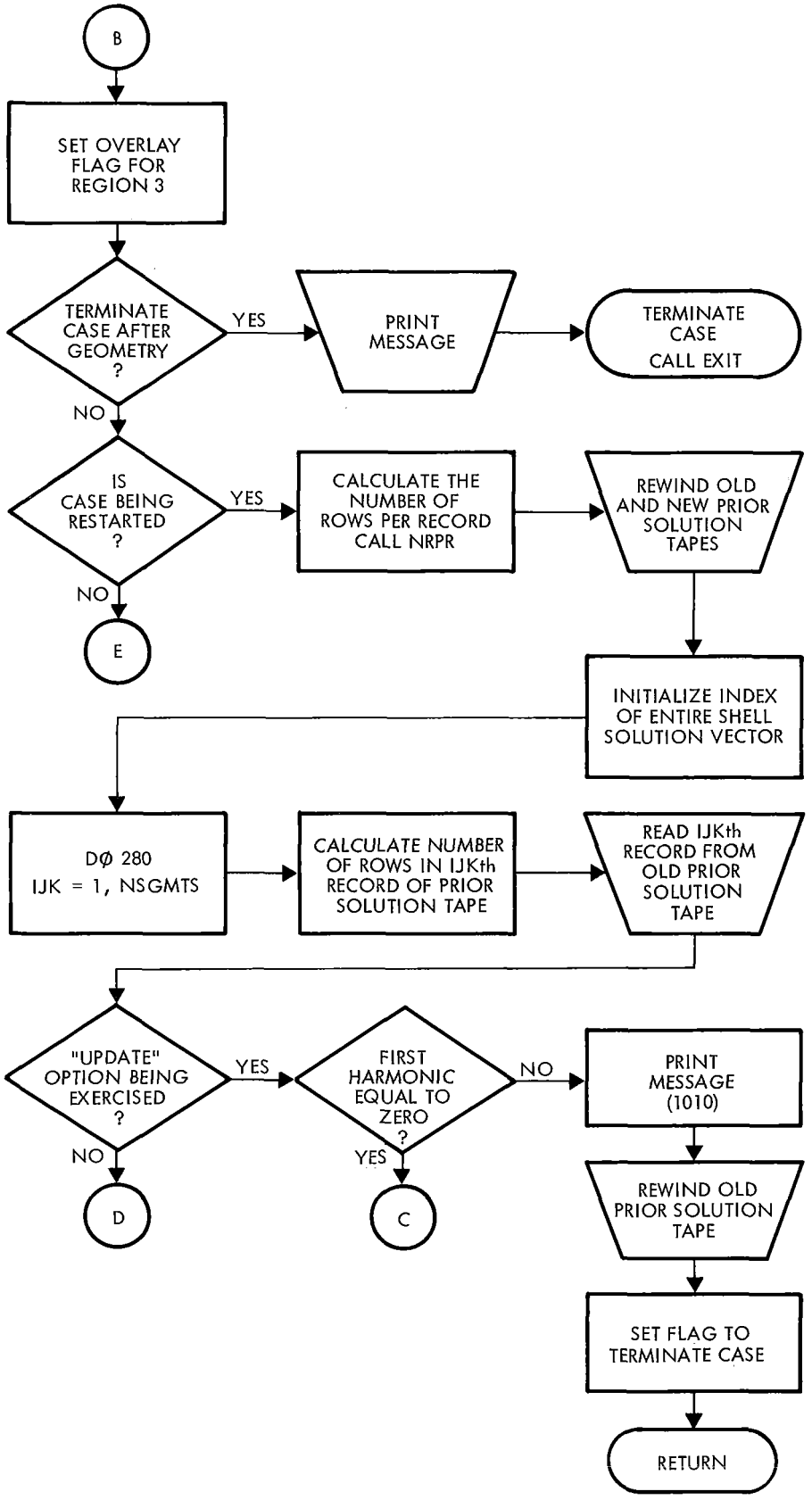


Figure 2.20. Subroutine MON2X (Continued)

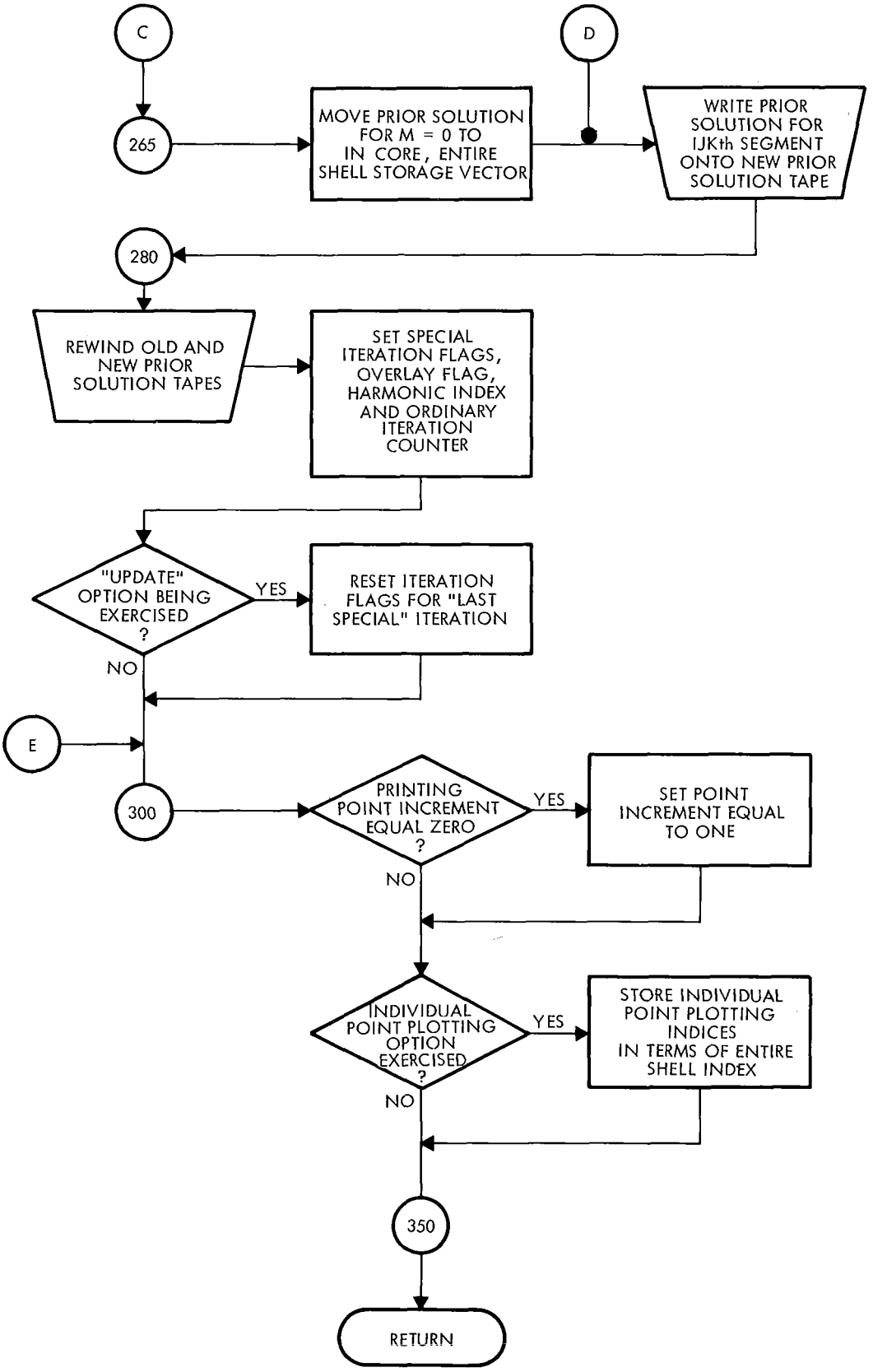


Figure 2.20. Subroutine MON2X (Continued)

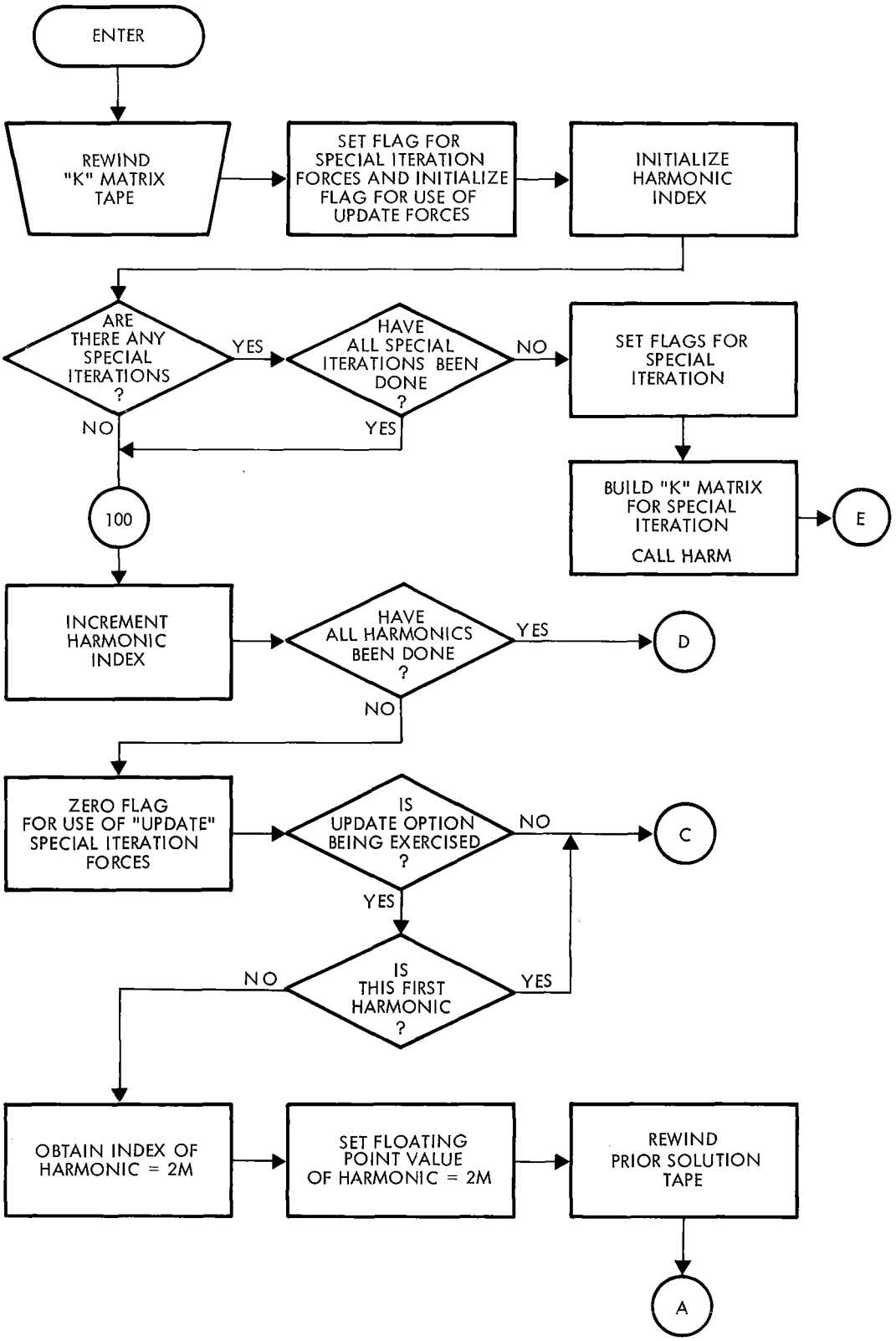


Figure 2.21. Subroutine MON3X

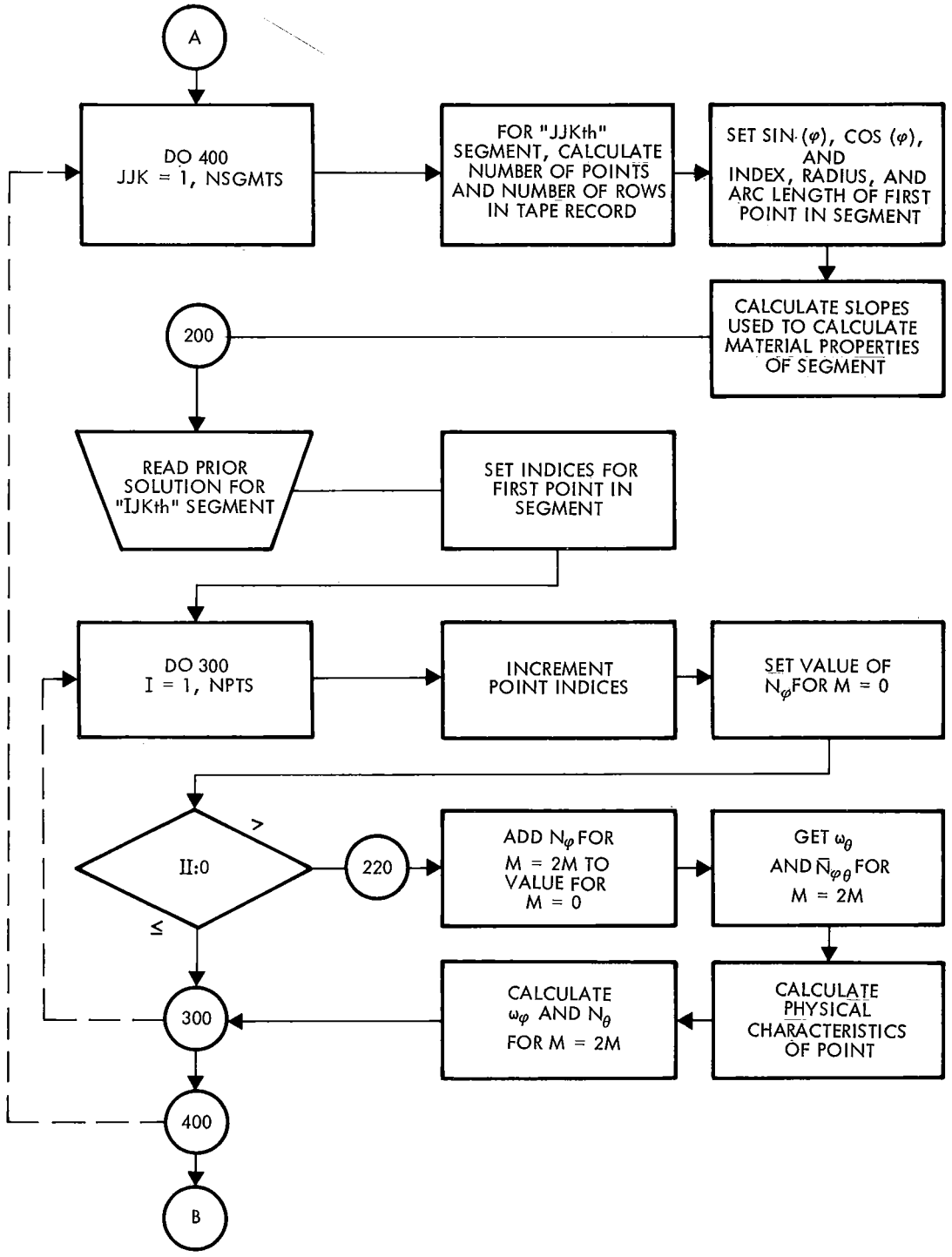


Figure 2.21. Subroutine MON3X (Continued)

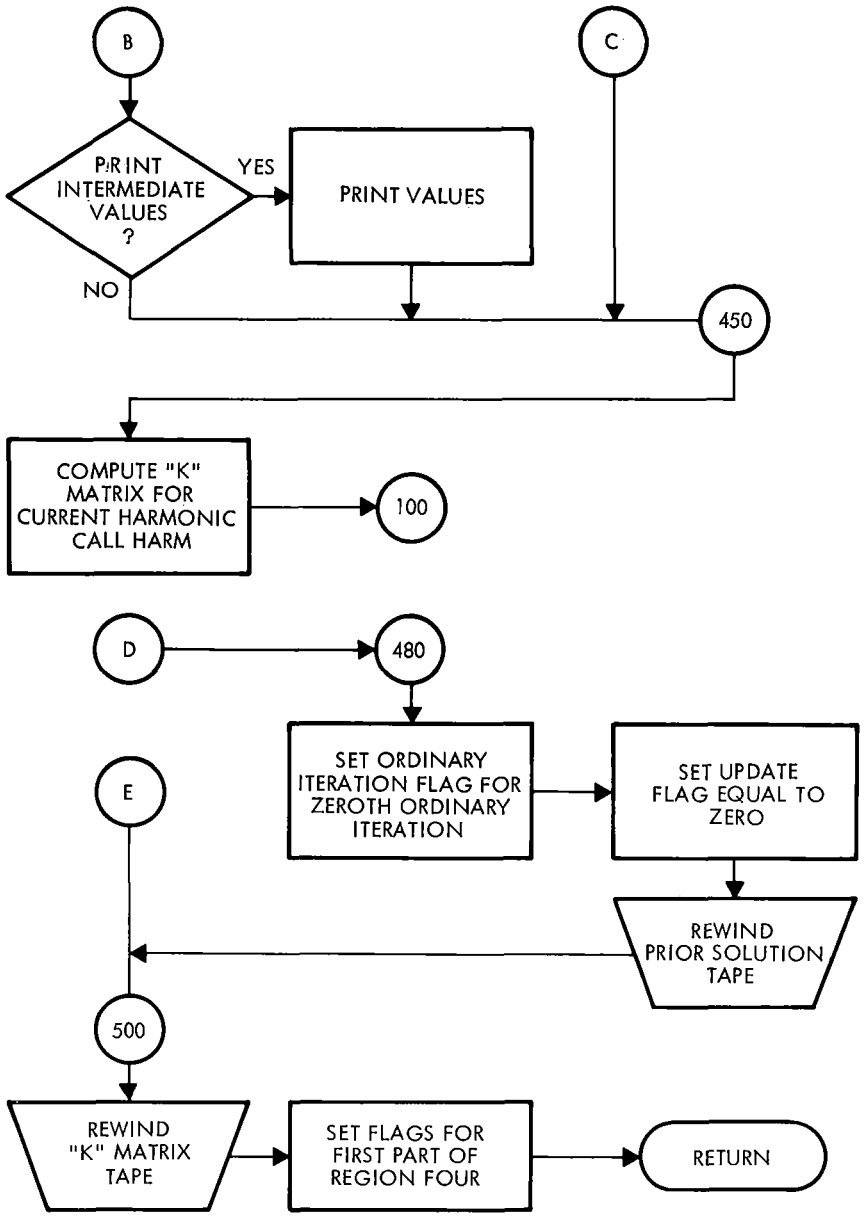


Figure 2.21. Subroutine MON3X (Continued)

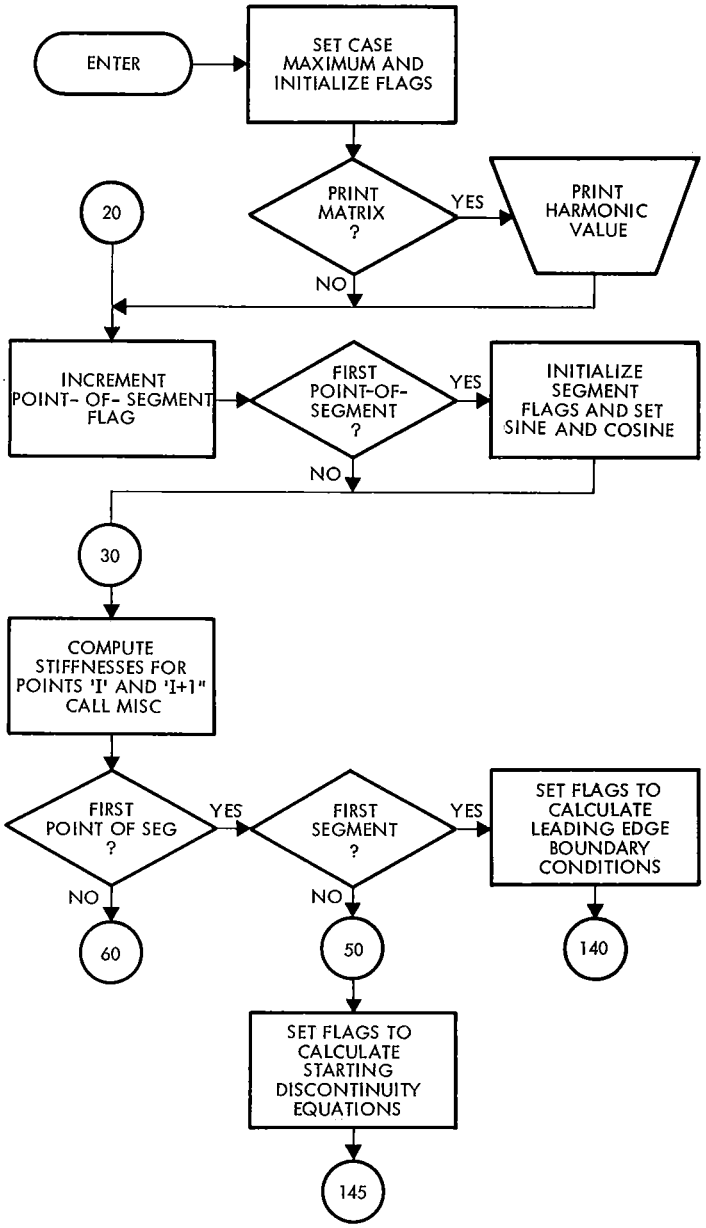


Figure 2.22. Subroutine HARMX

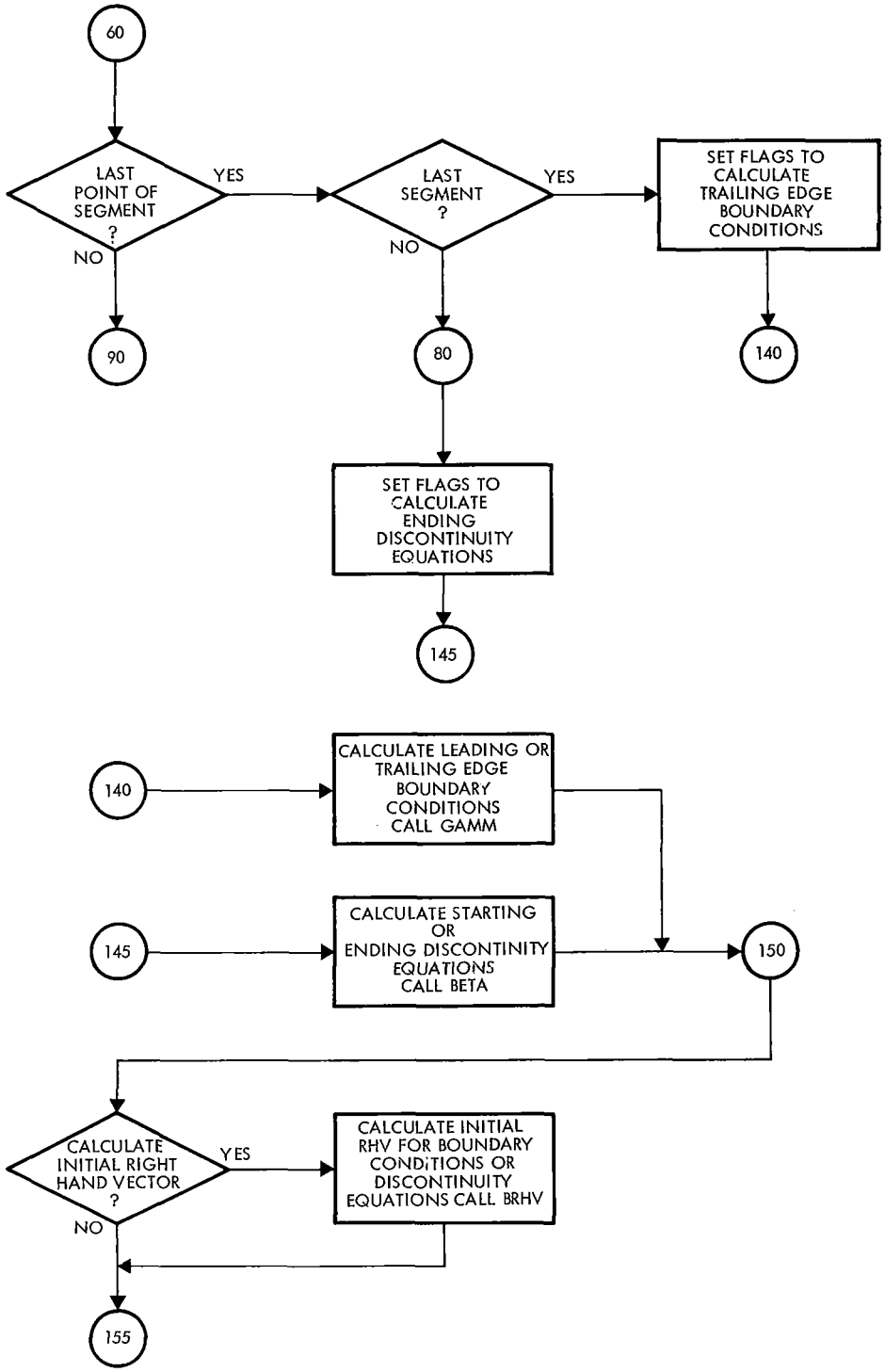


Figure 2.22. Subroutine HARMX (Continued)

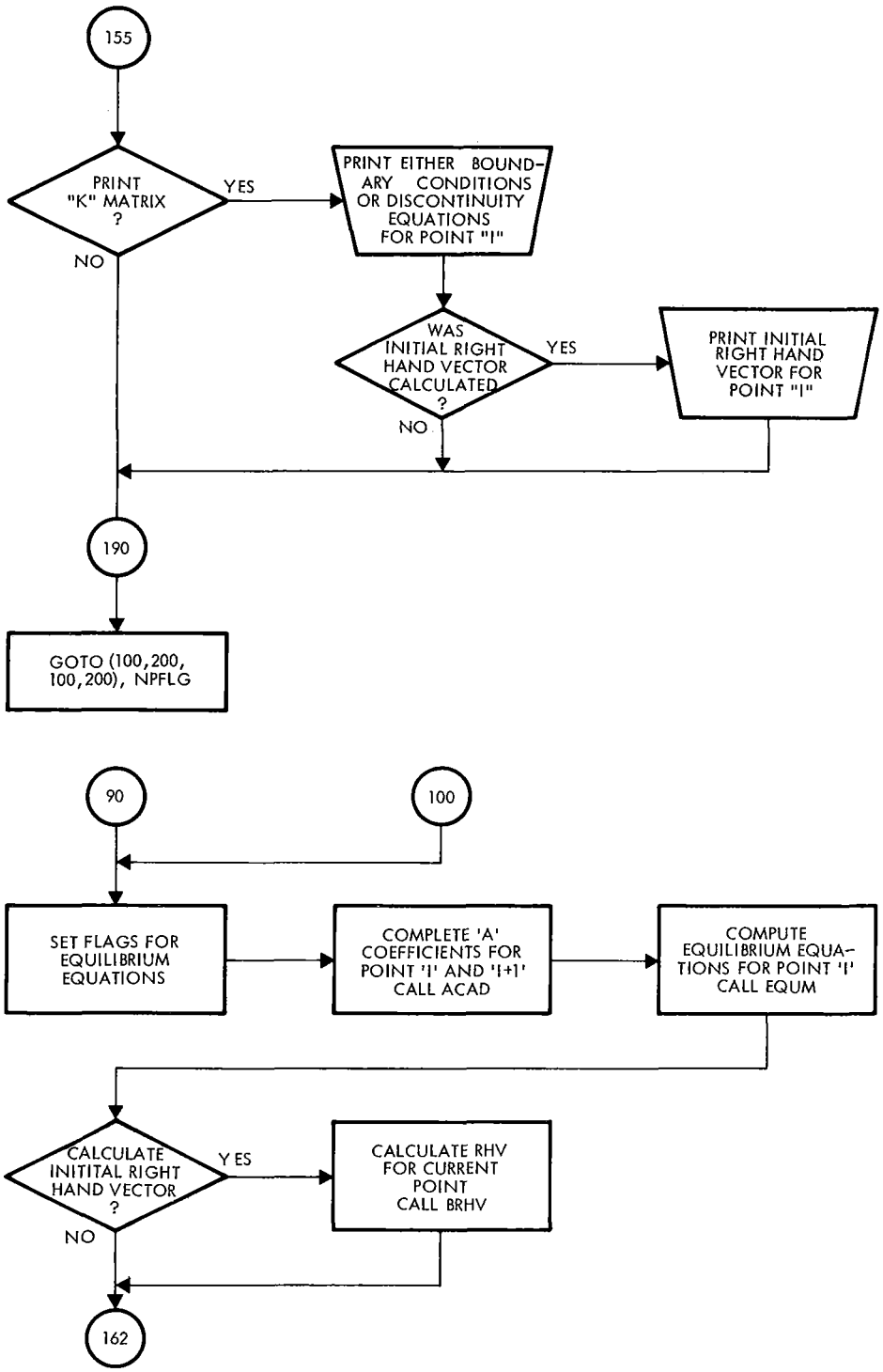


Figure 2.22. Subroutine HARMX (Continued)

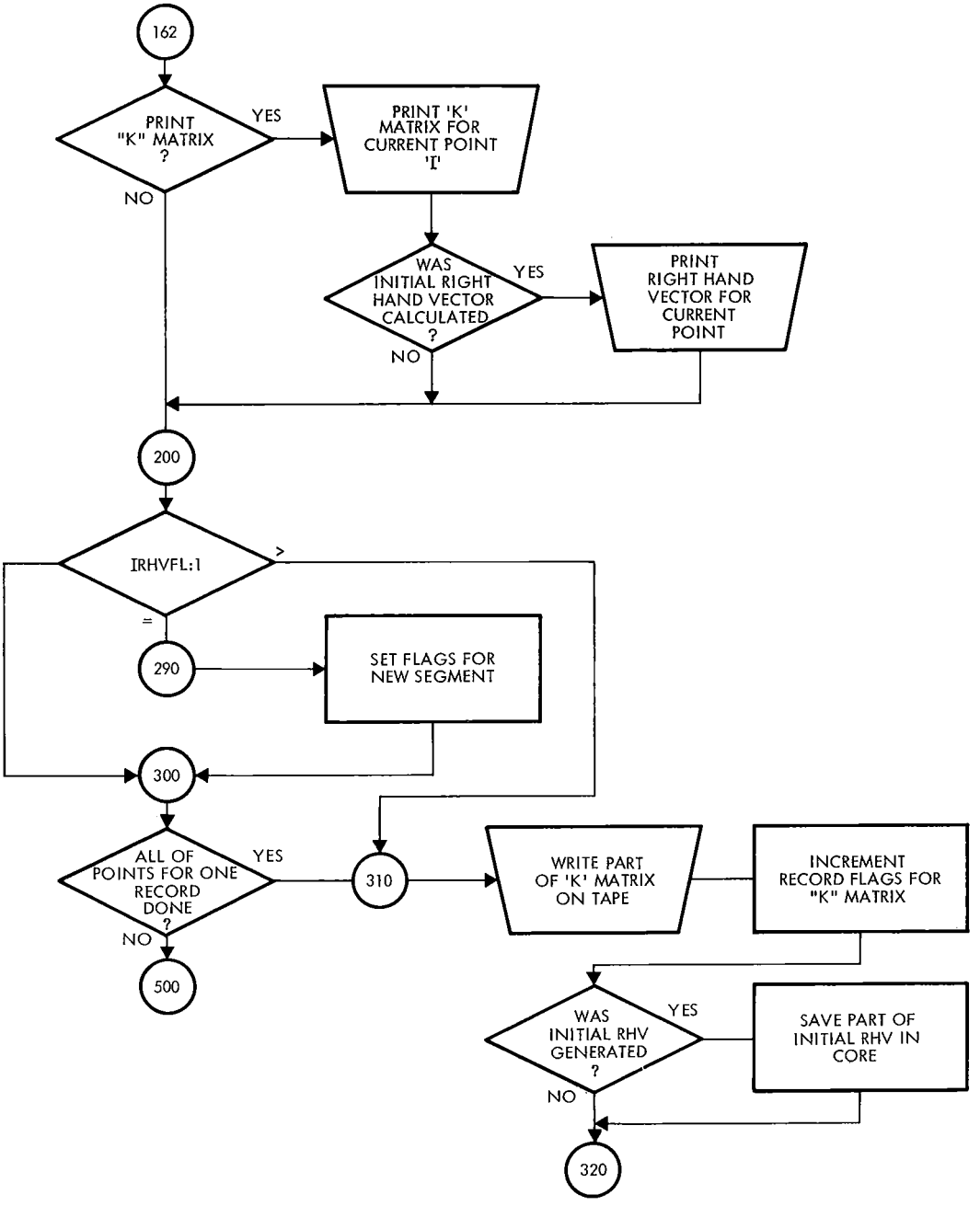


Figure 2.22. Subroutine HARMX (Continued)

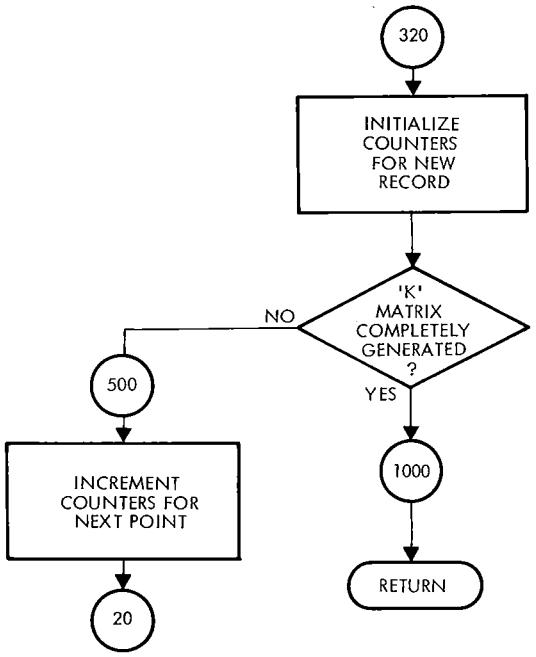


Figure 2.22. Subroutine HARMX (Continued)

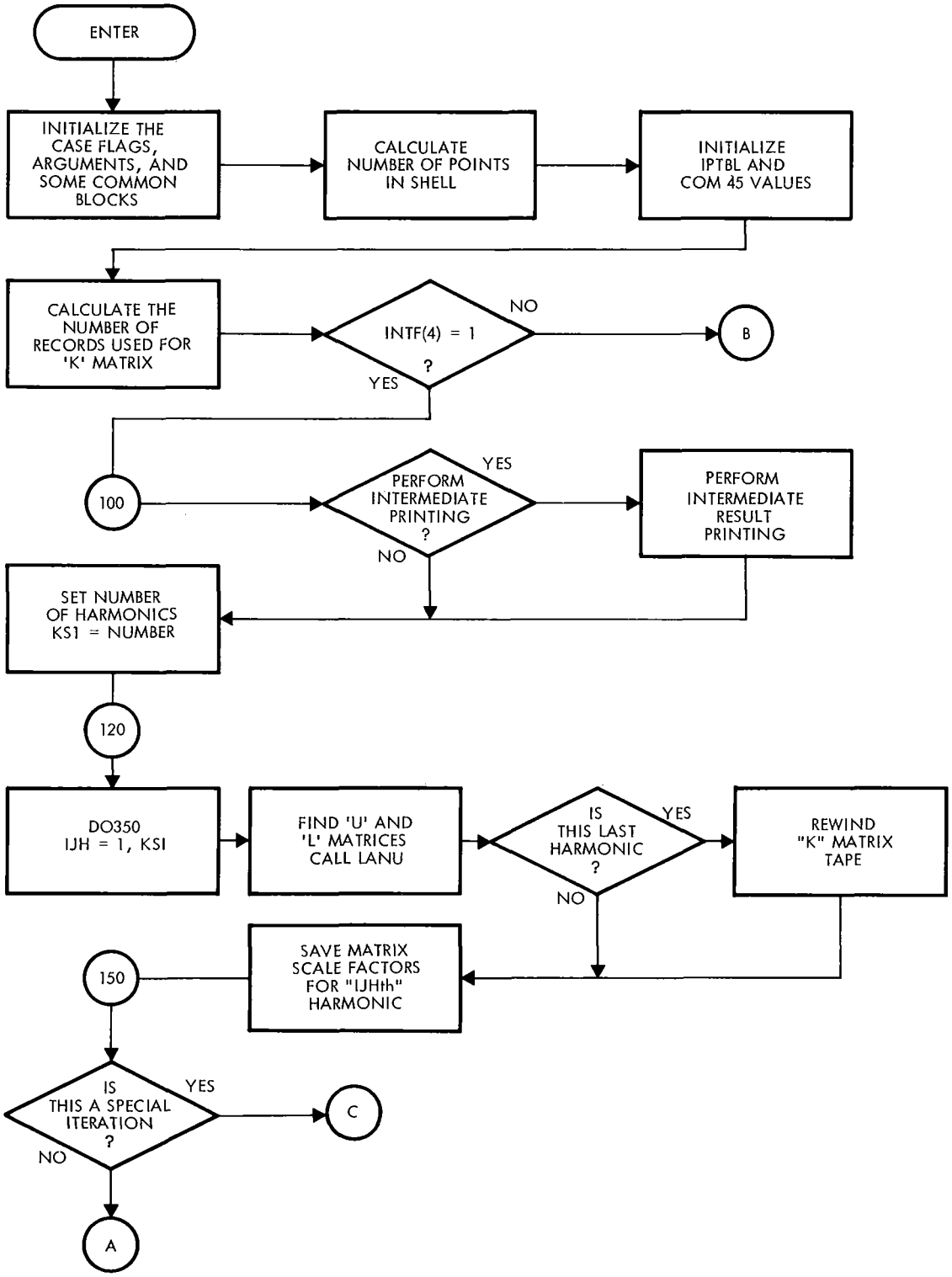


Figure 2. 23. Subroutine MON4X

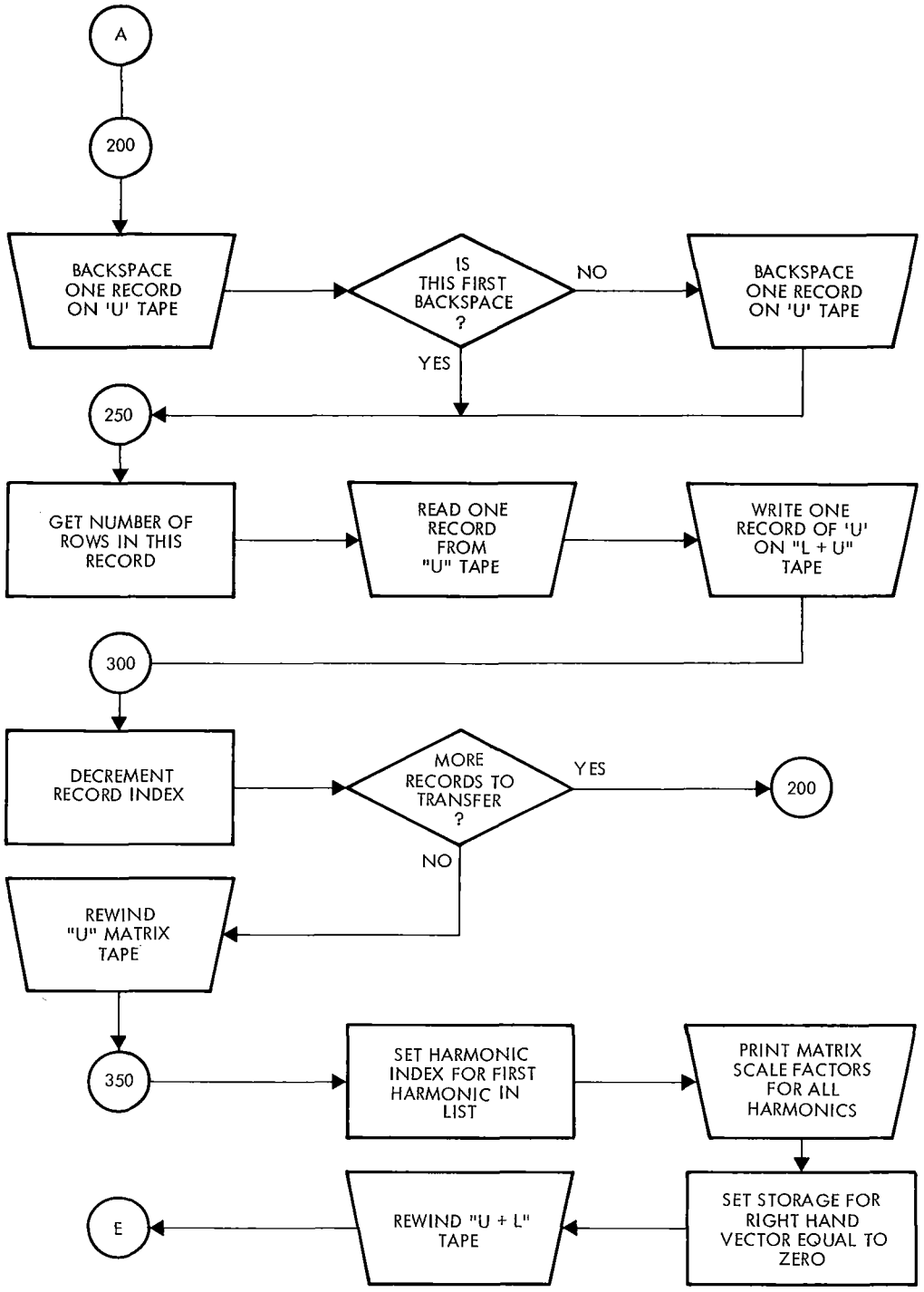


Figure 2.23. Subroutine MON4X (Continued)

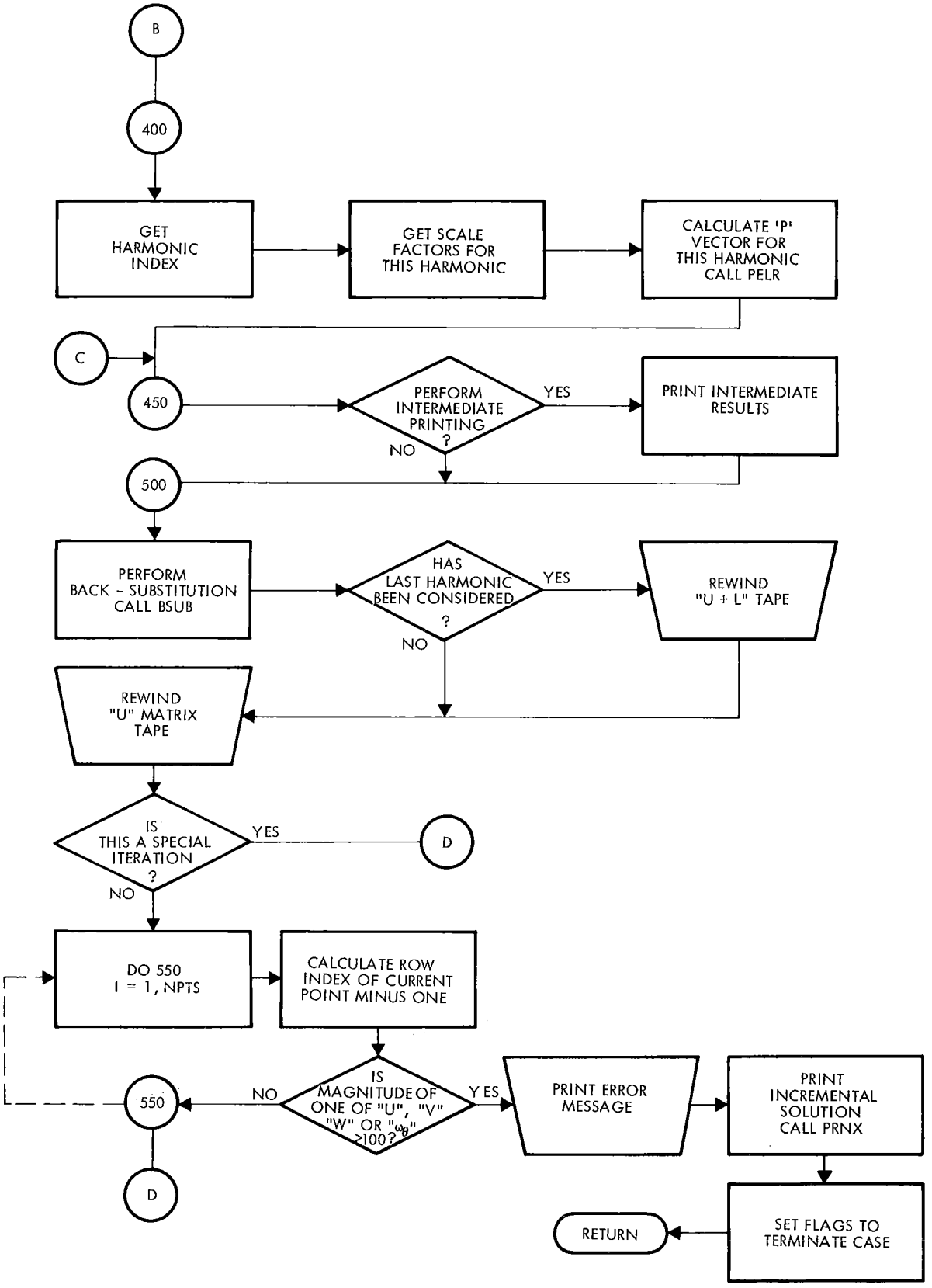


Figure 2.23. Subroutine MON4X (Continued)

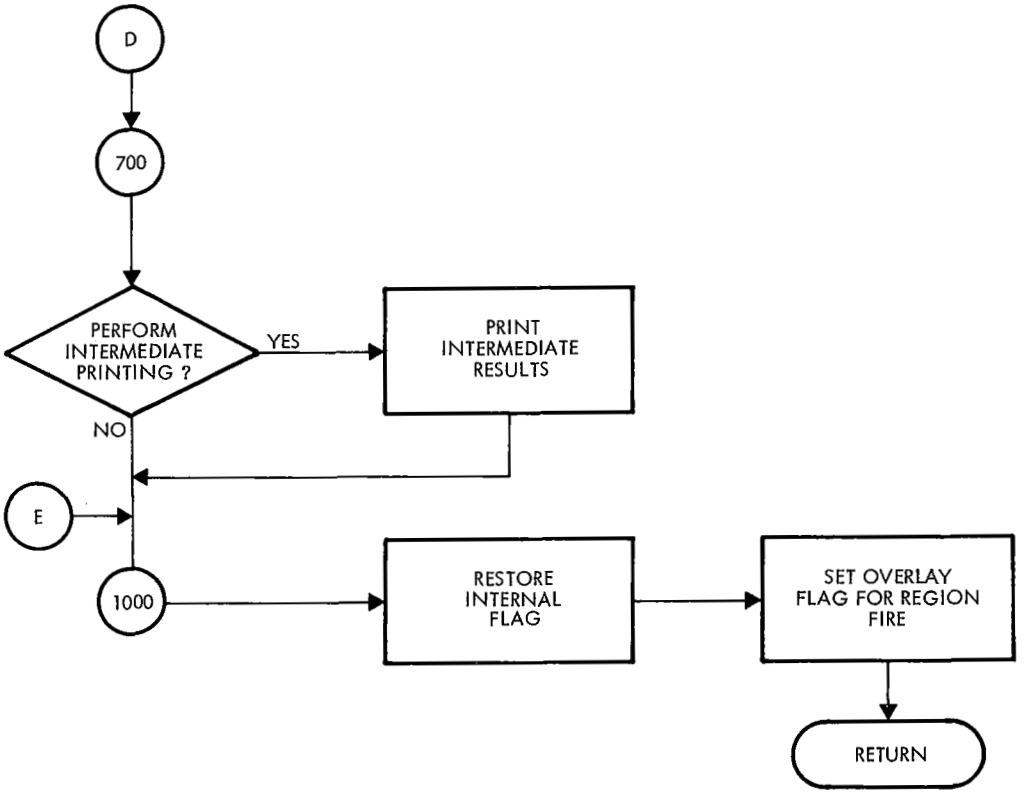


Figure 2.23. Subroutine MON4X (Continued)

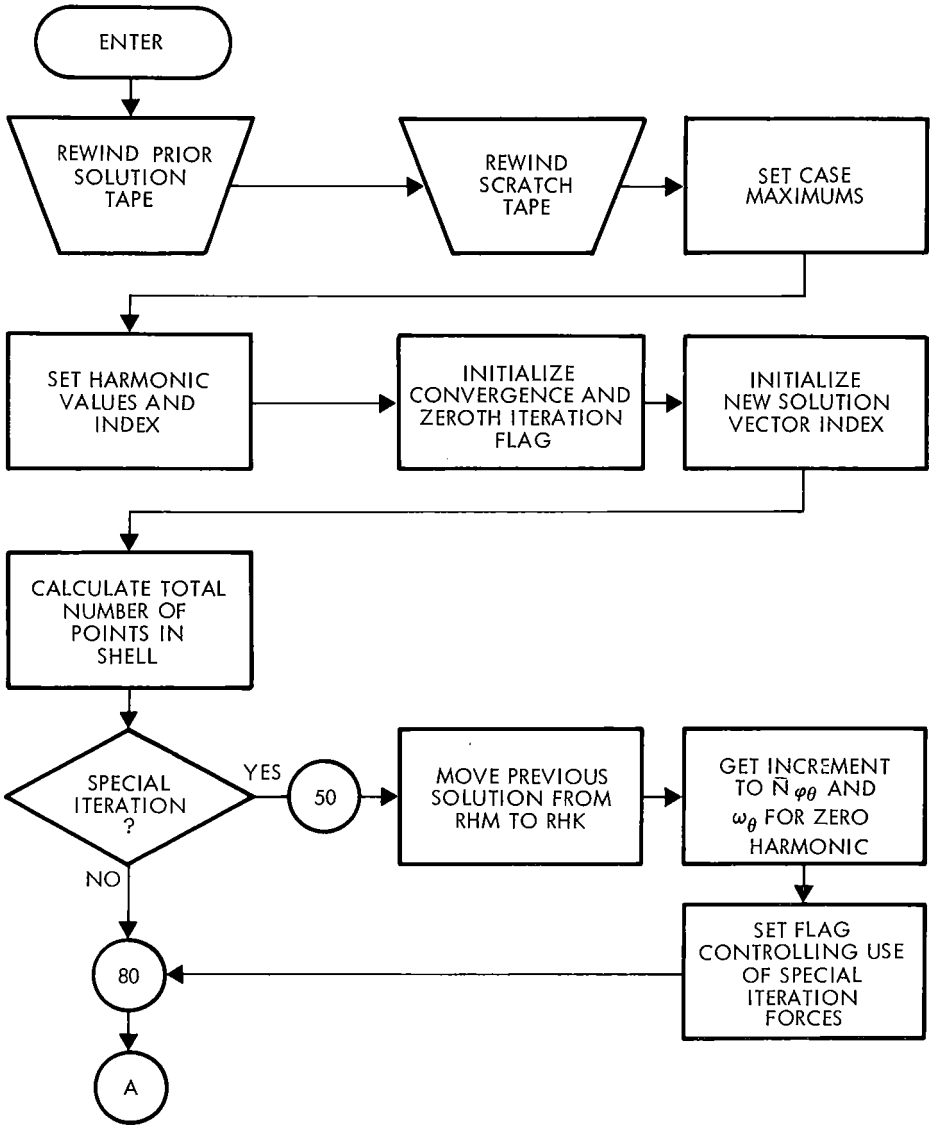


Figure 2.24. Subroutine MON5X

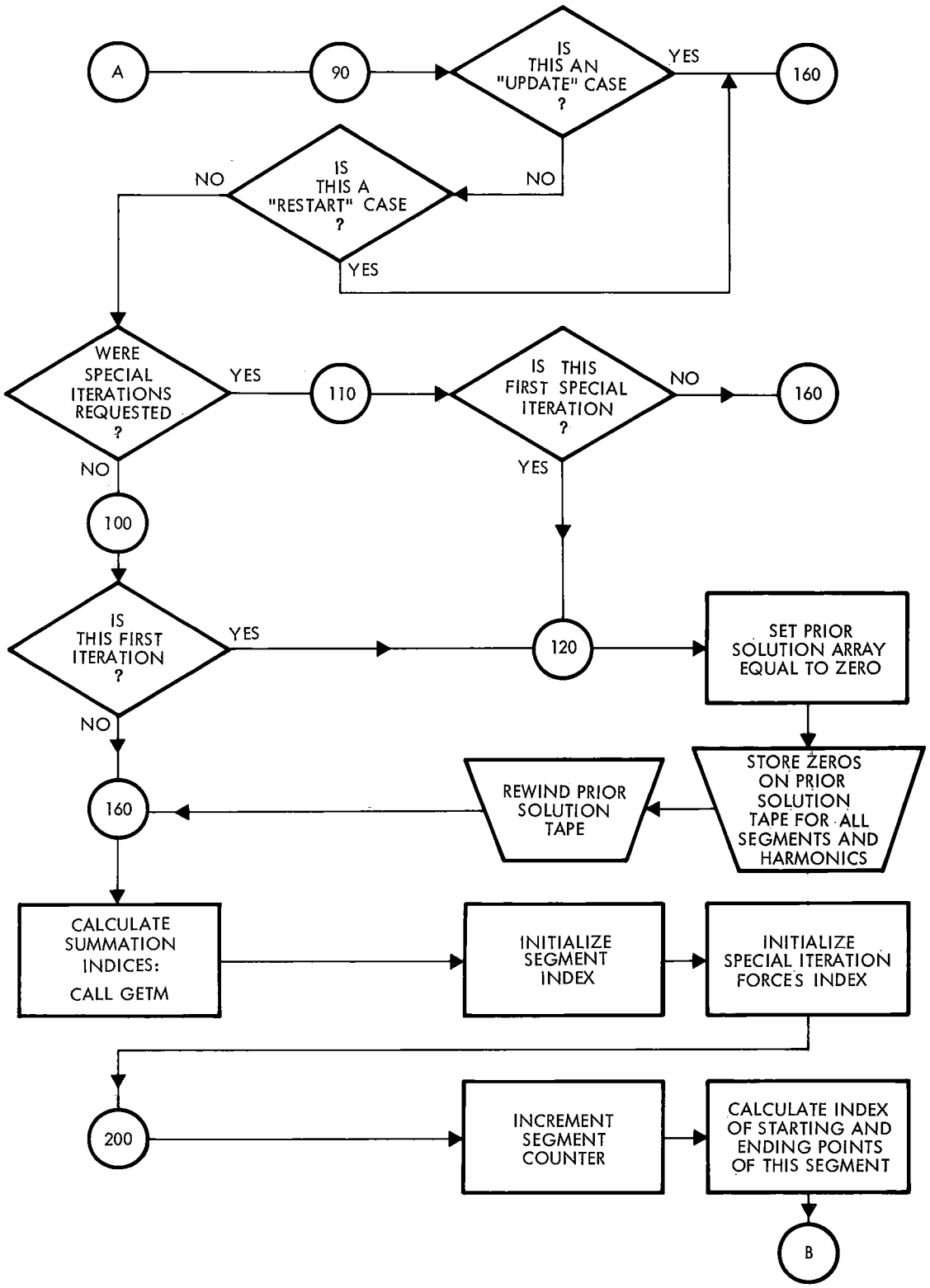


Figure 2.24. Subroutine MON5X (Continued)

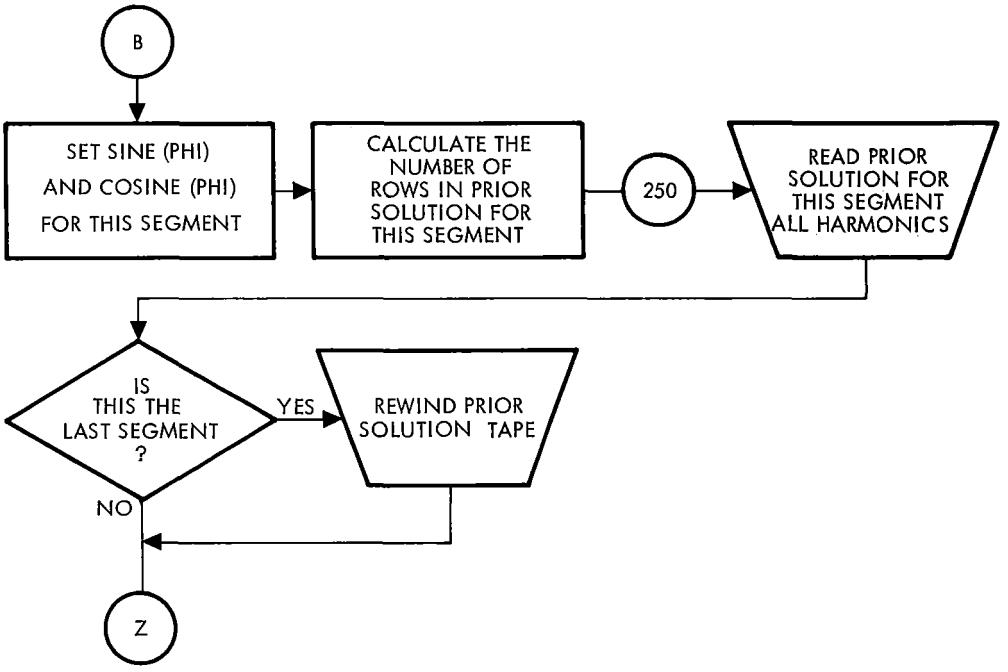


Figure 2.24. Subroutine MON5X (Continued)

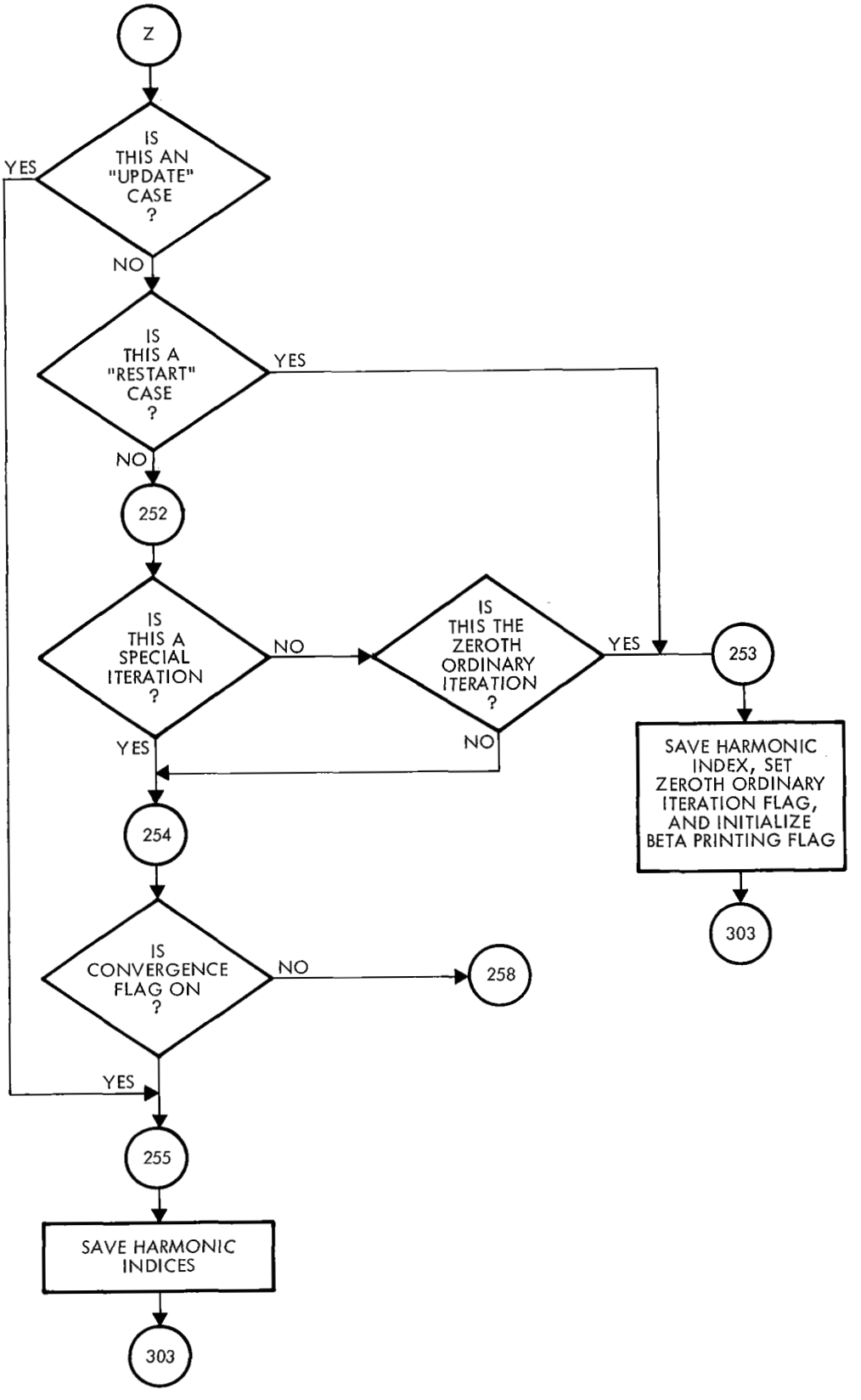


Figure 2.24. Subroutine MON5X (Continued)

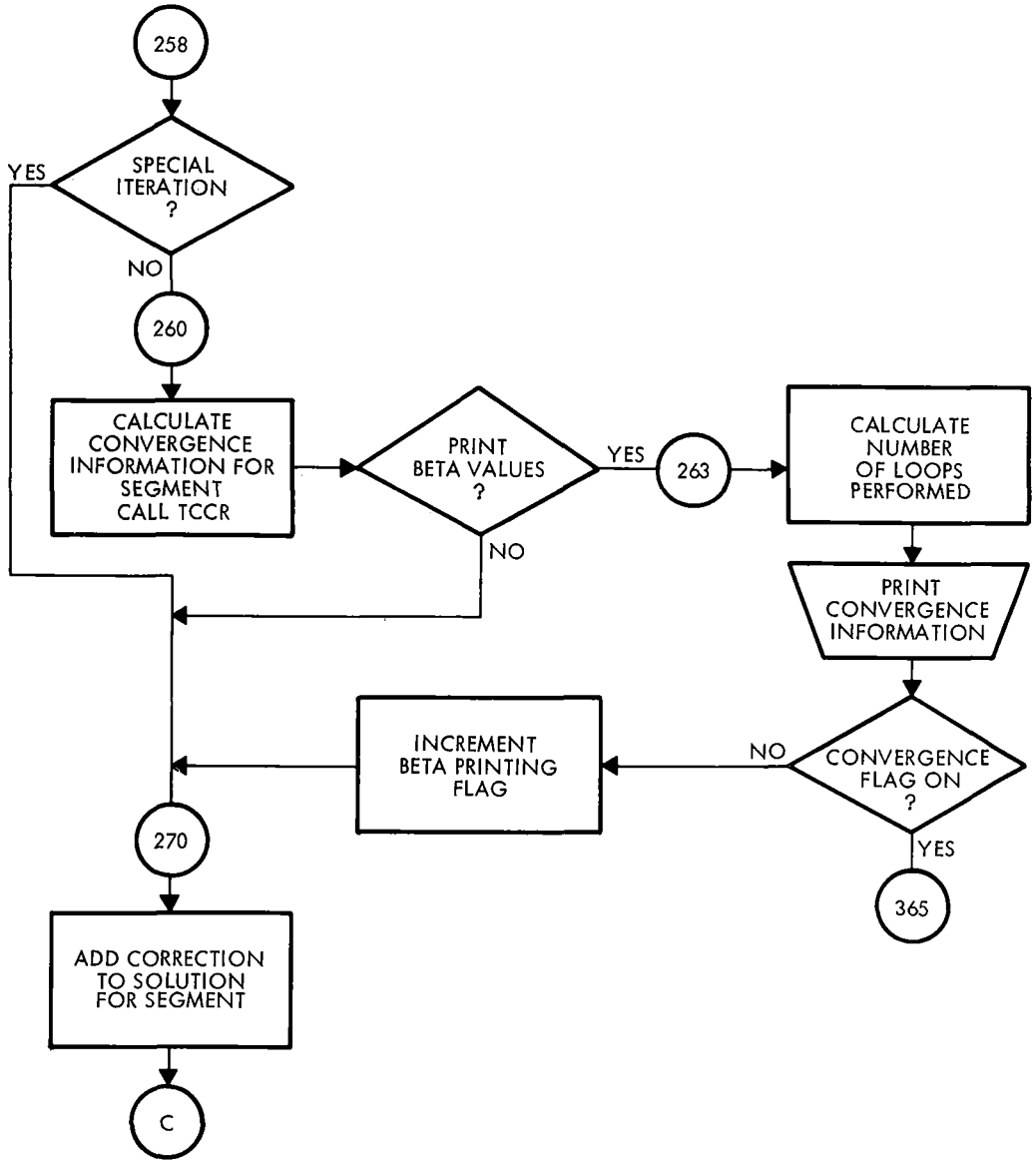


Figure 2. 24. Subroutine MON5X (Continued)

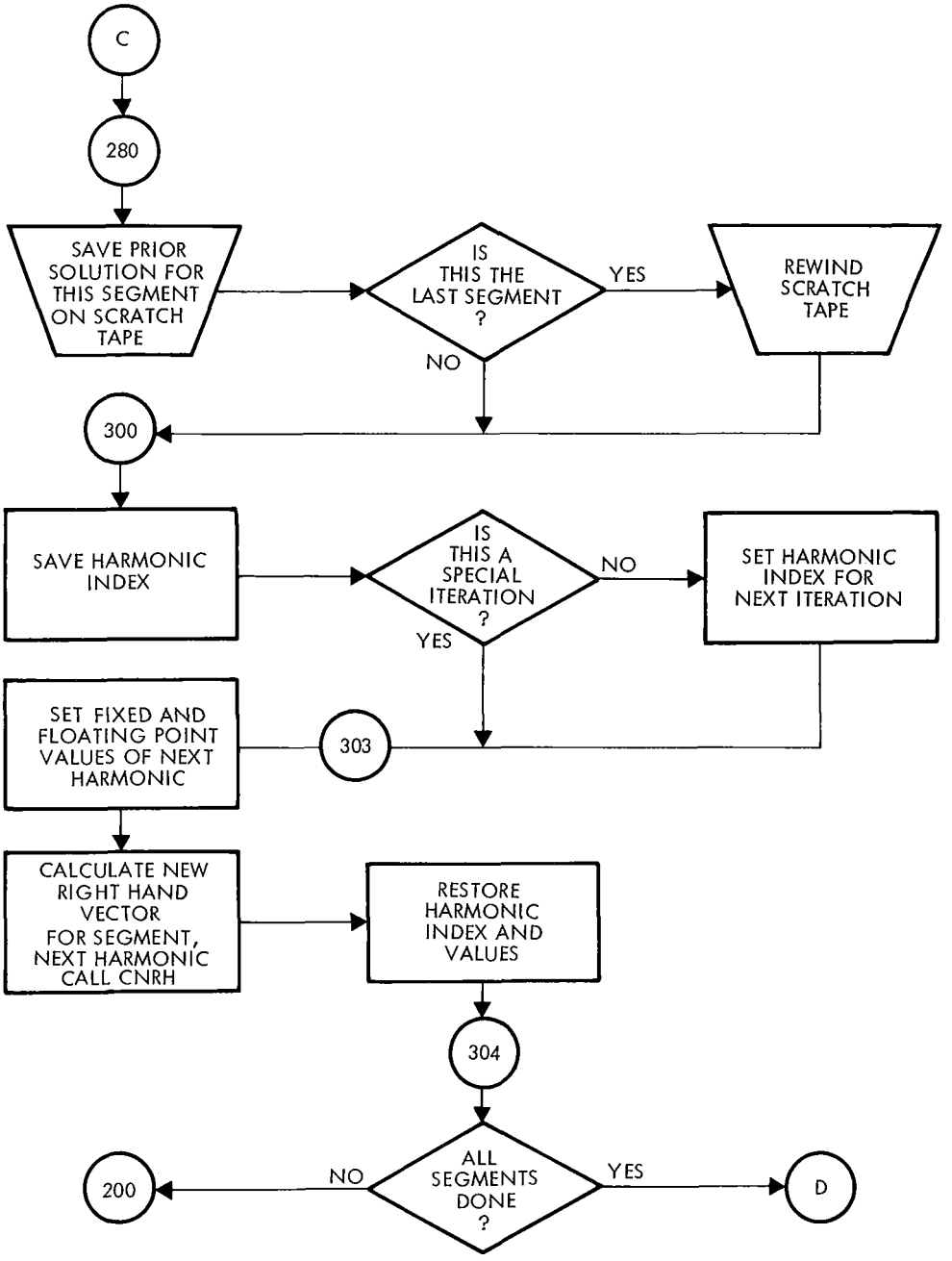


Figure 2.24. Subroutine MON5X (Continued)

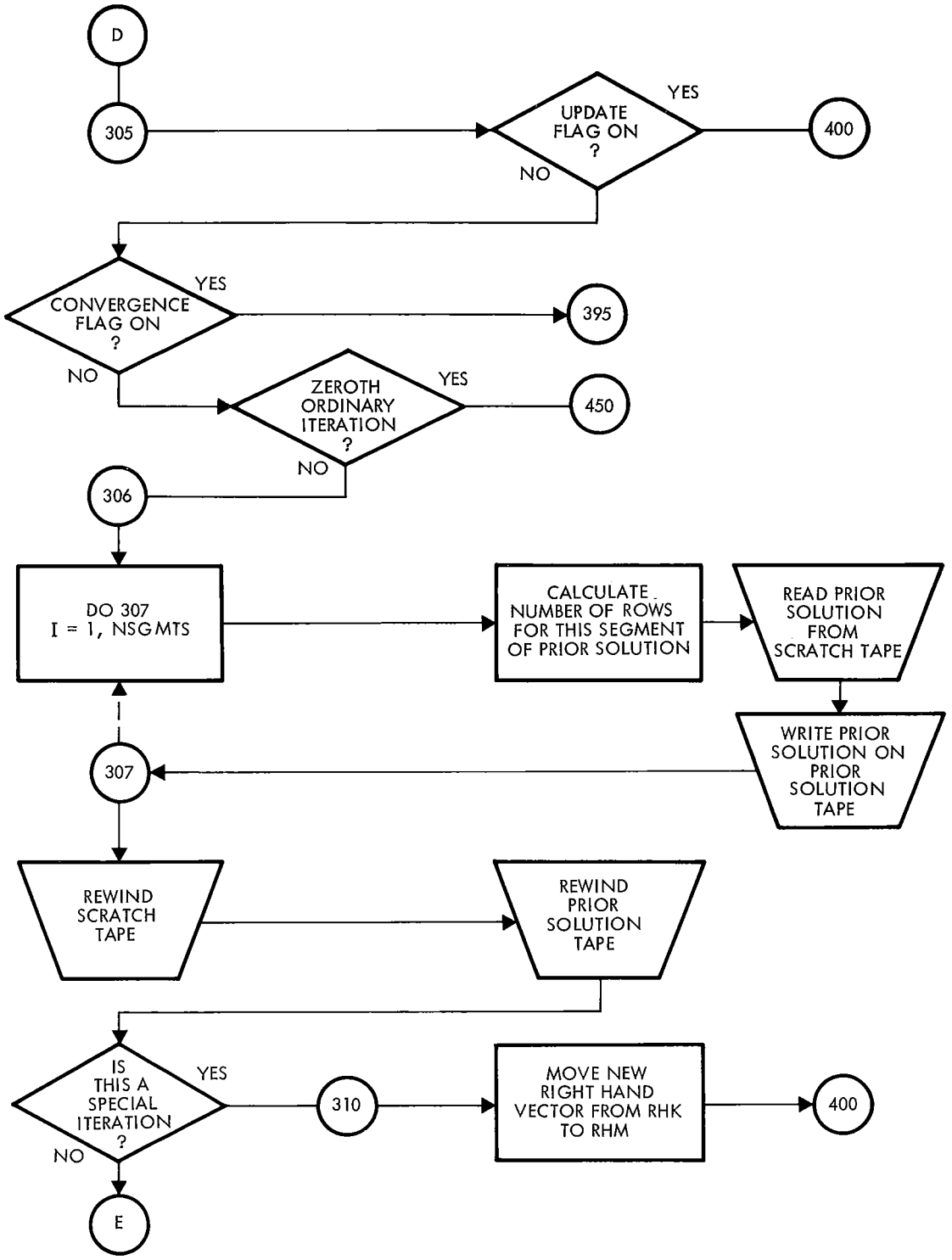


Figure 2.24. Subroutine MON5X (Continued)

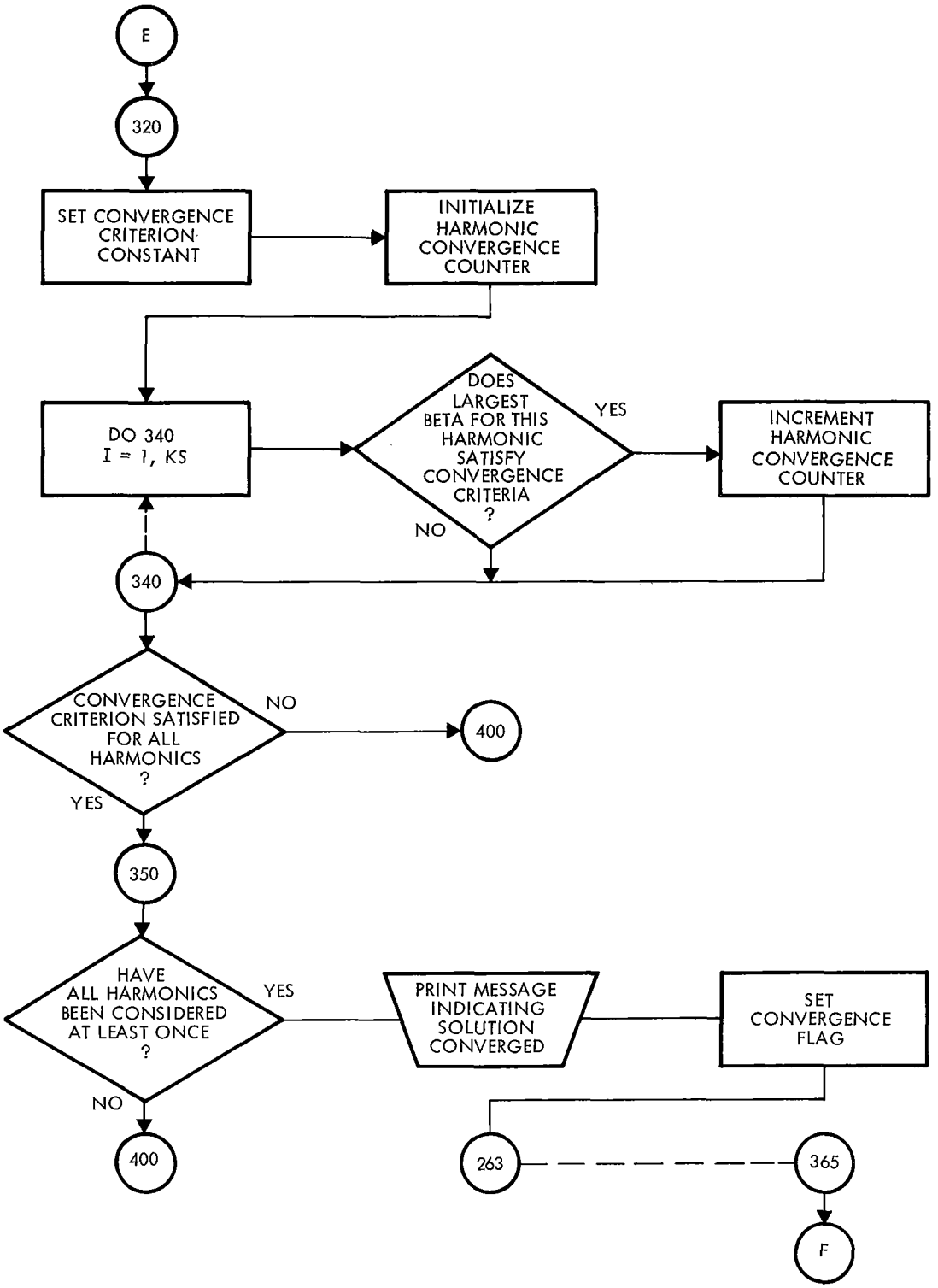


Figure 2.24. Subroutine MON5X (Continued)

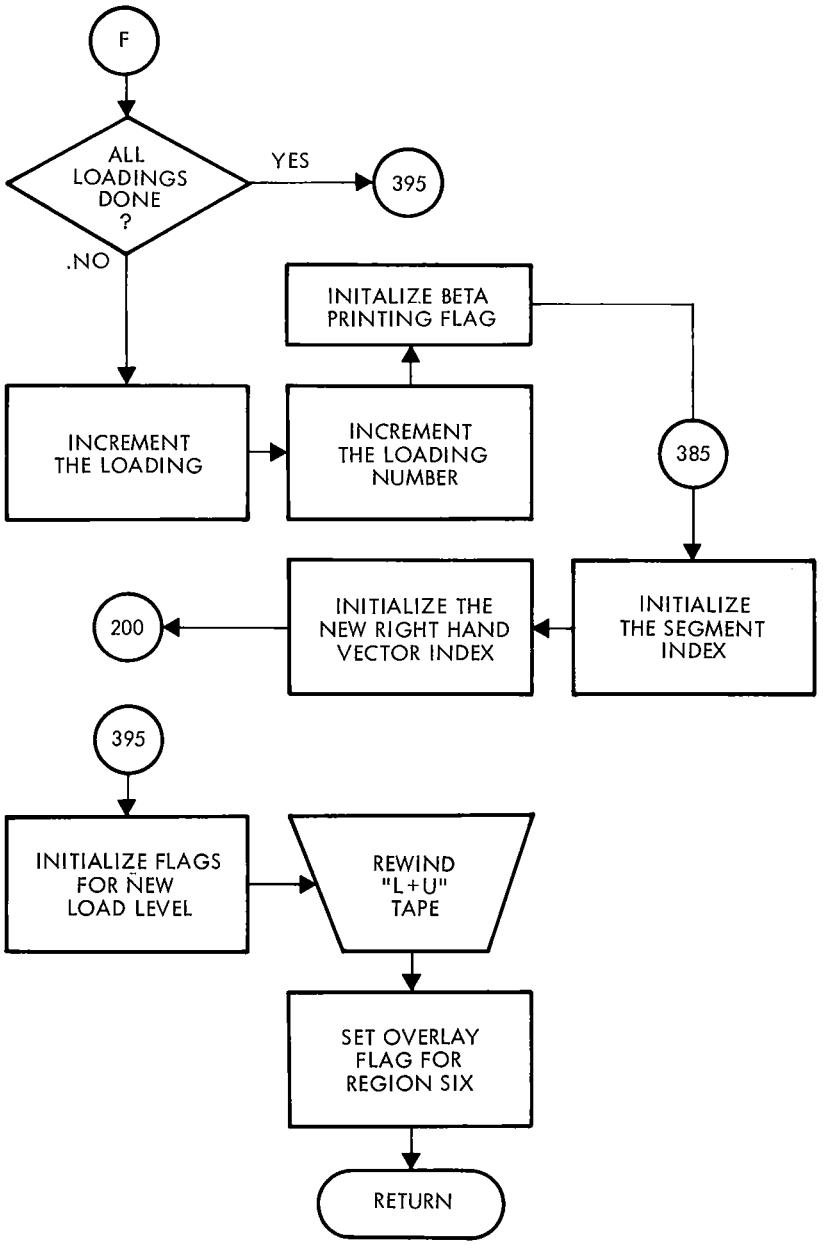


Figure 2.24. Subroutine MON5X (Continued)

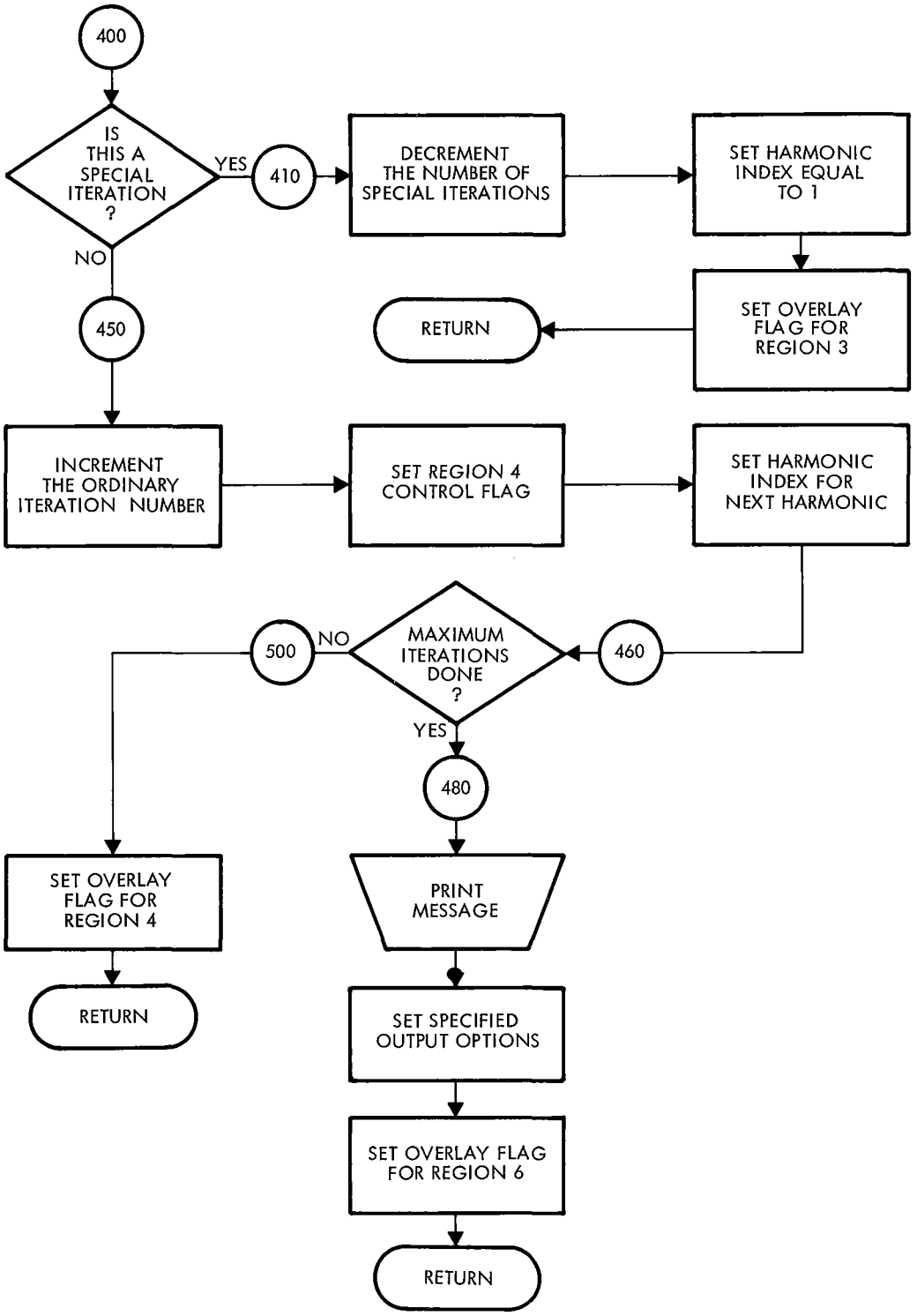


Figure 2.24. Subroutine MON5X (Continued)

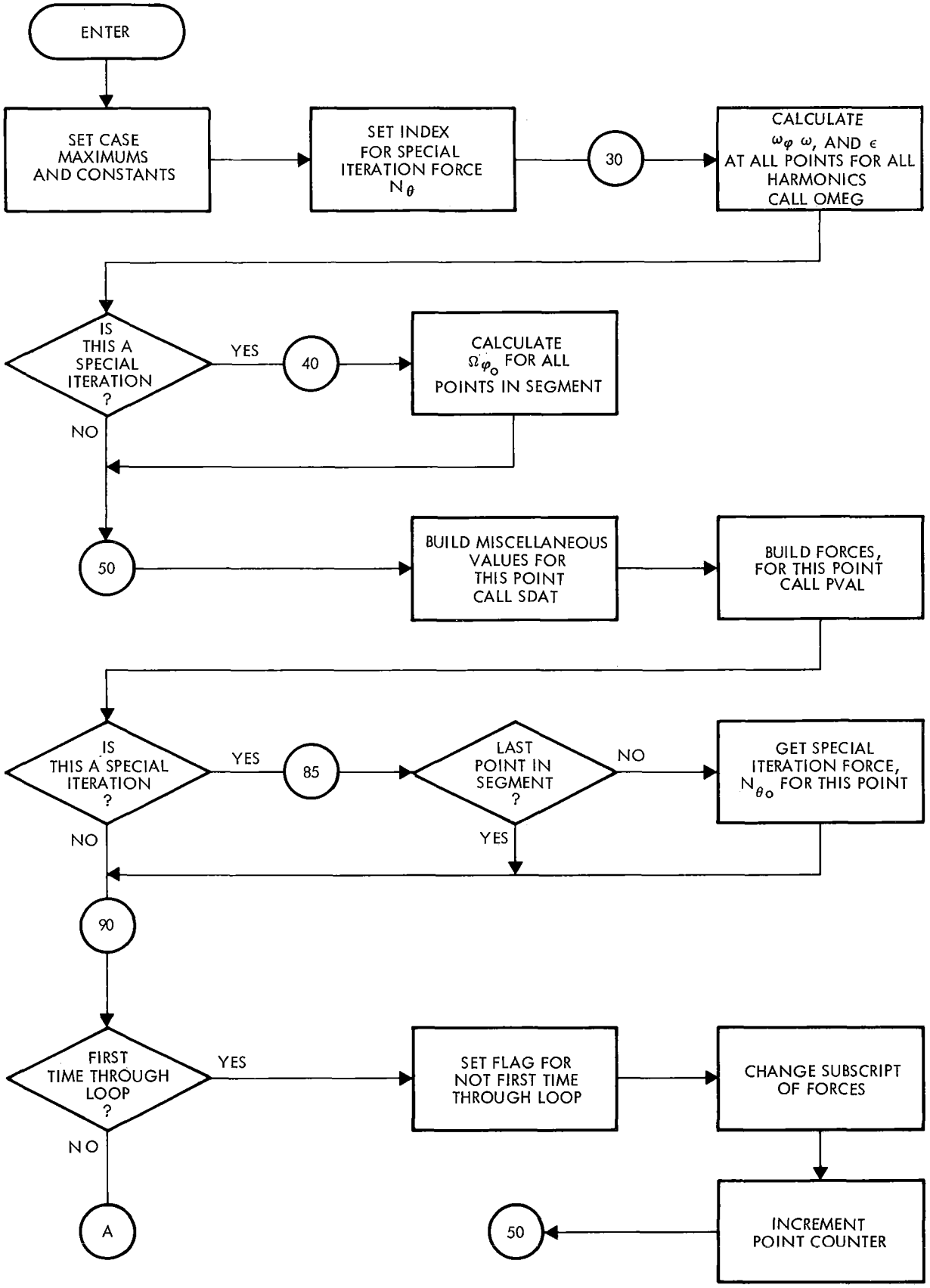


Figure 2.25. Subroutine CNRHX

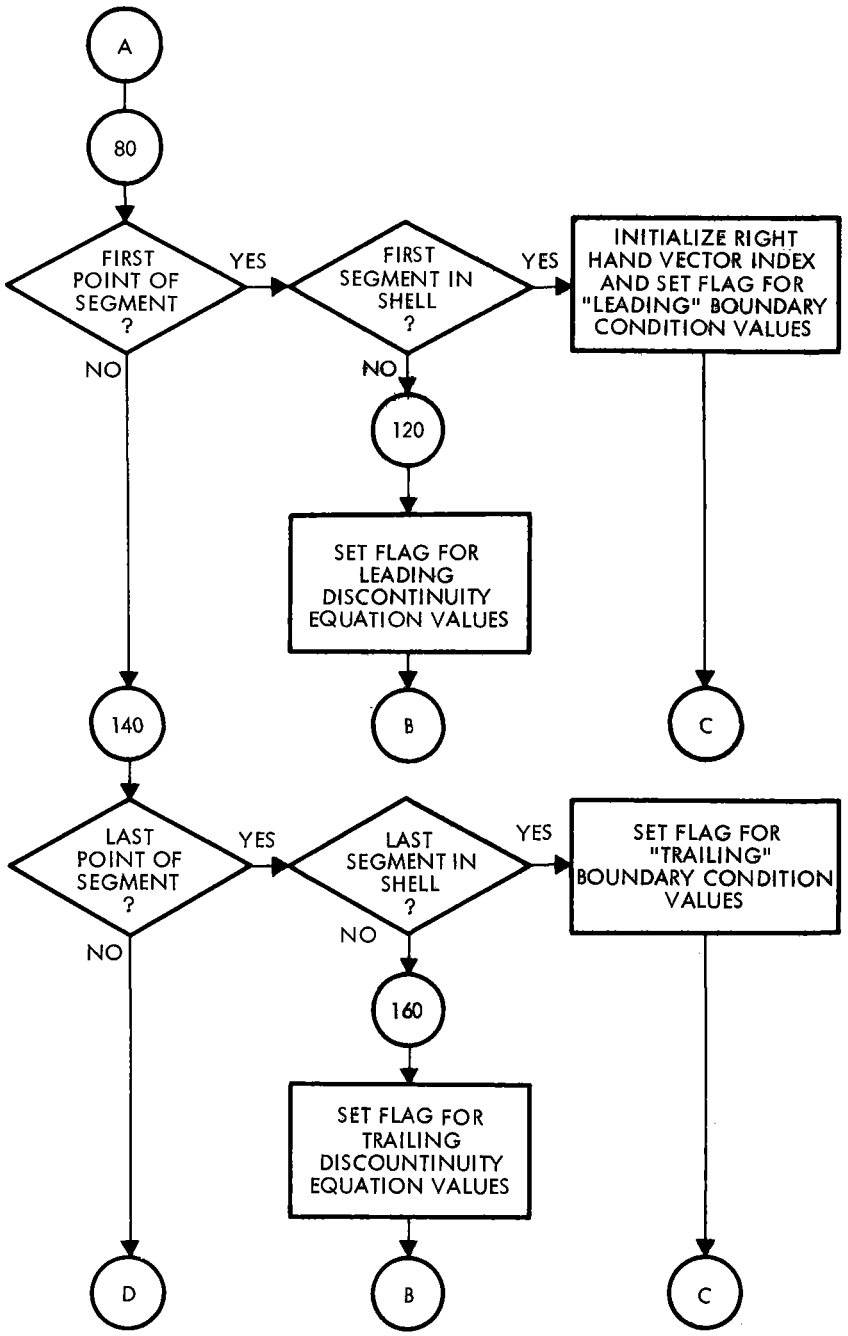


Figure 2. 25. Subroutine CNRHX (Continued)

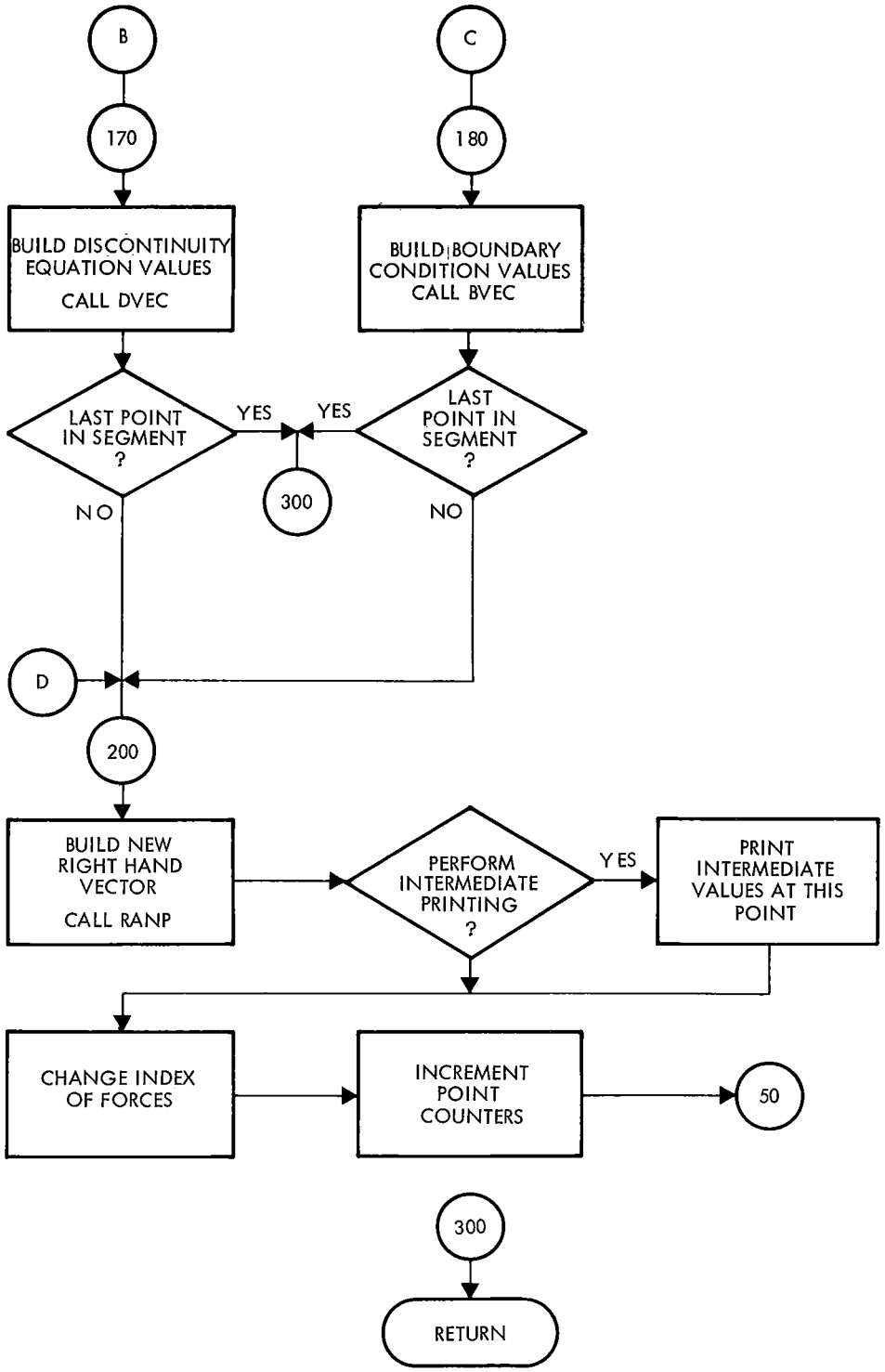


Figure 2.25. Subroutine CNRHX (Continued)

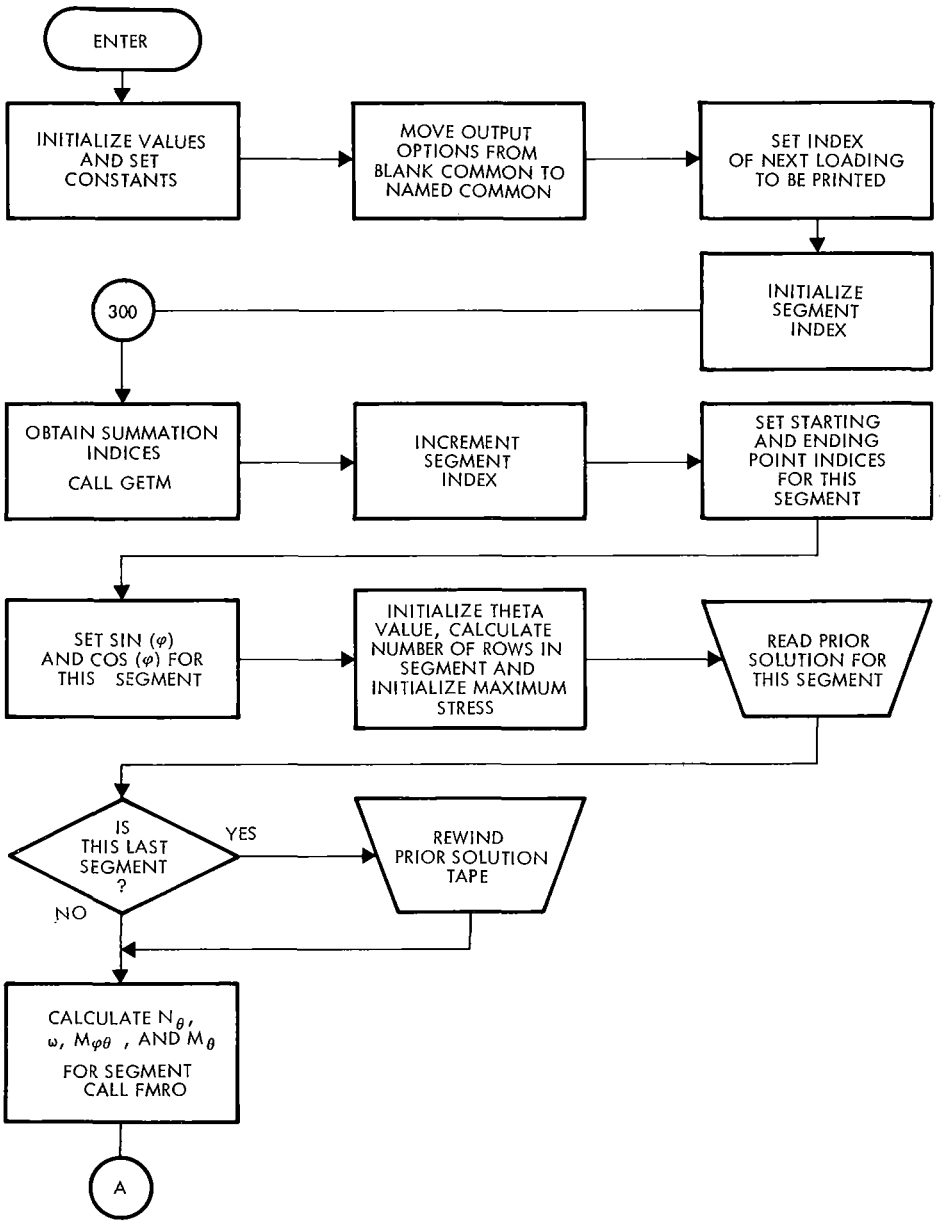


Figure 2.26. Subroutine MON6X

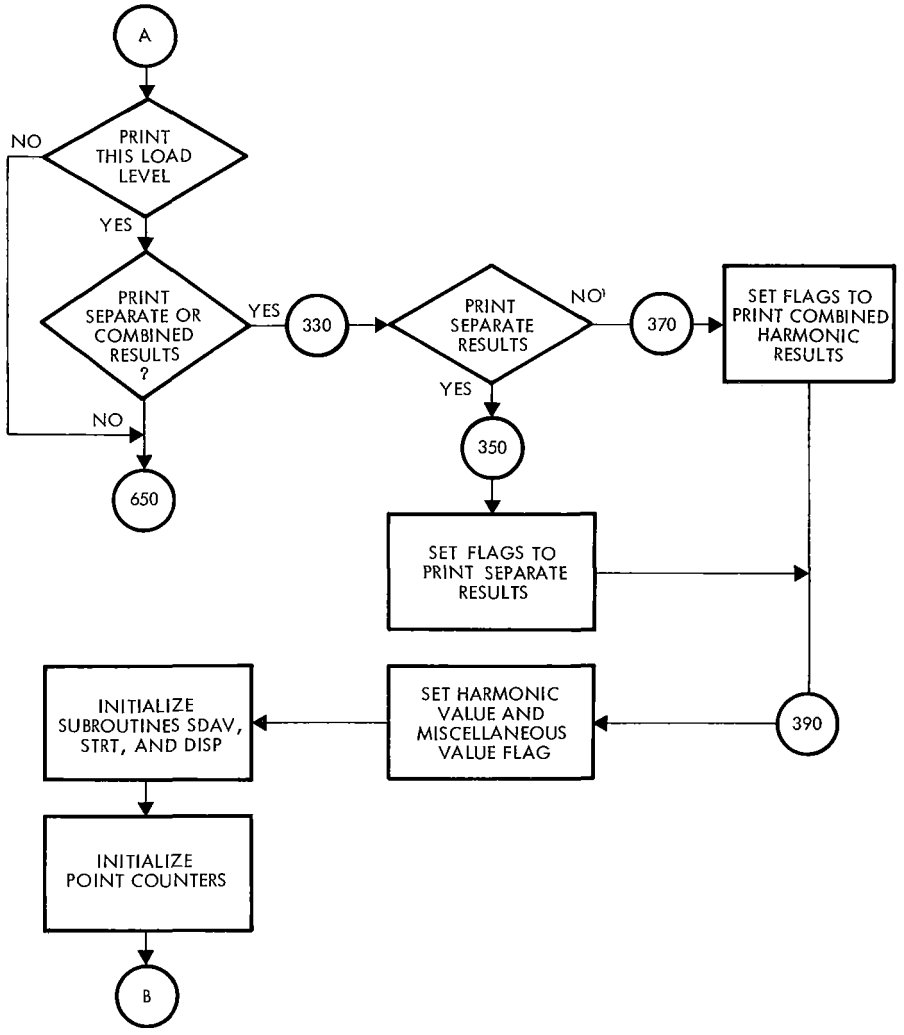
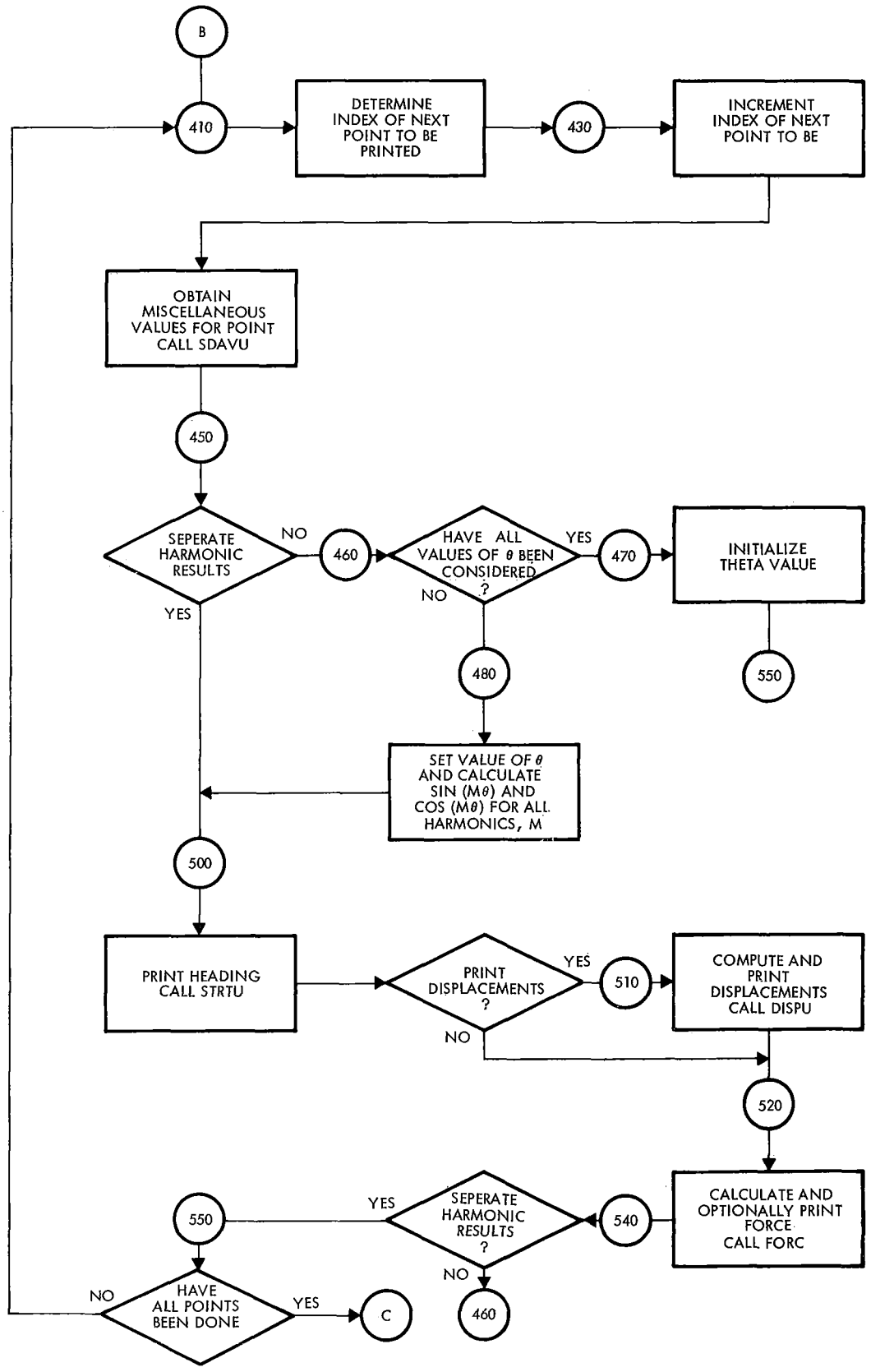


Figure 2.26. Subroutine MON6X (Continued)



2.26. Subroutine MON6X (Continued)

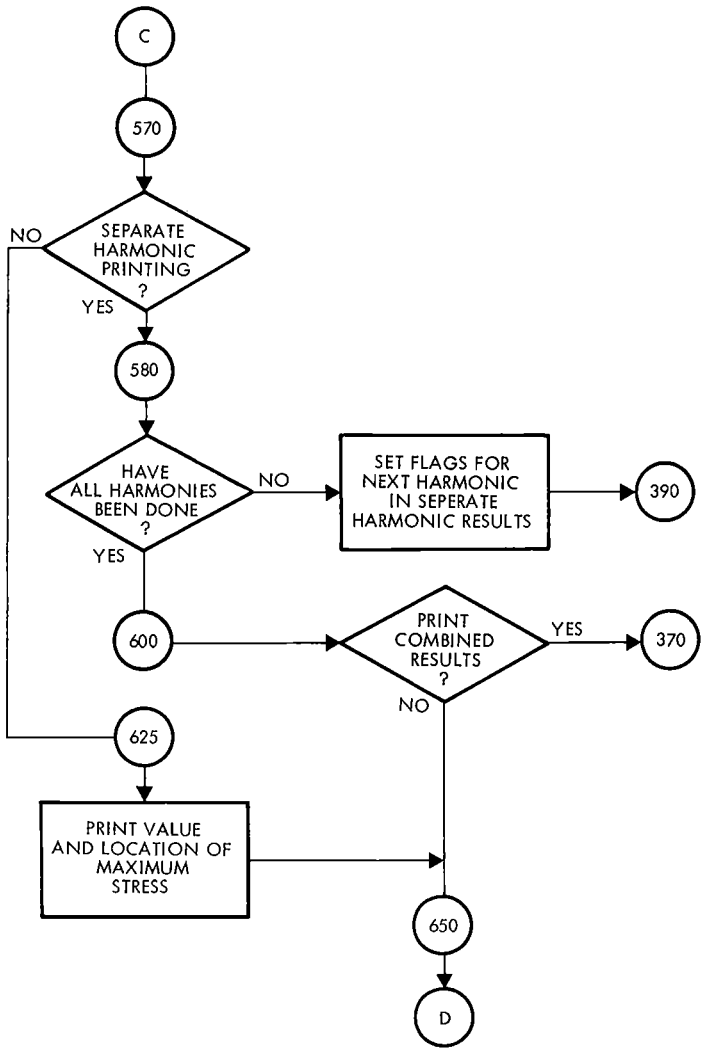


Figure 2. 26. Subroutine MON6X (Continued)

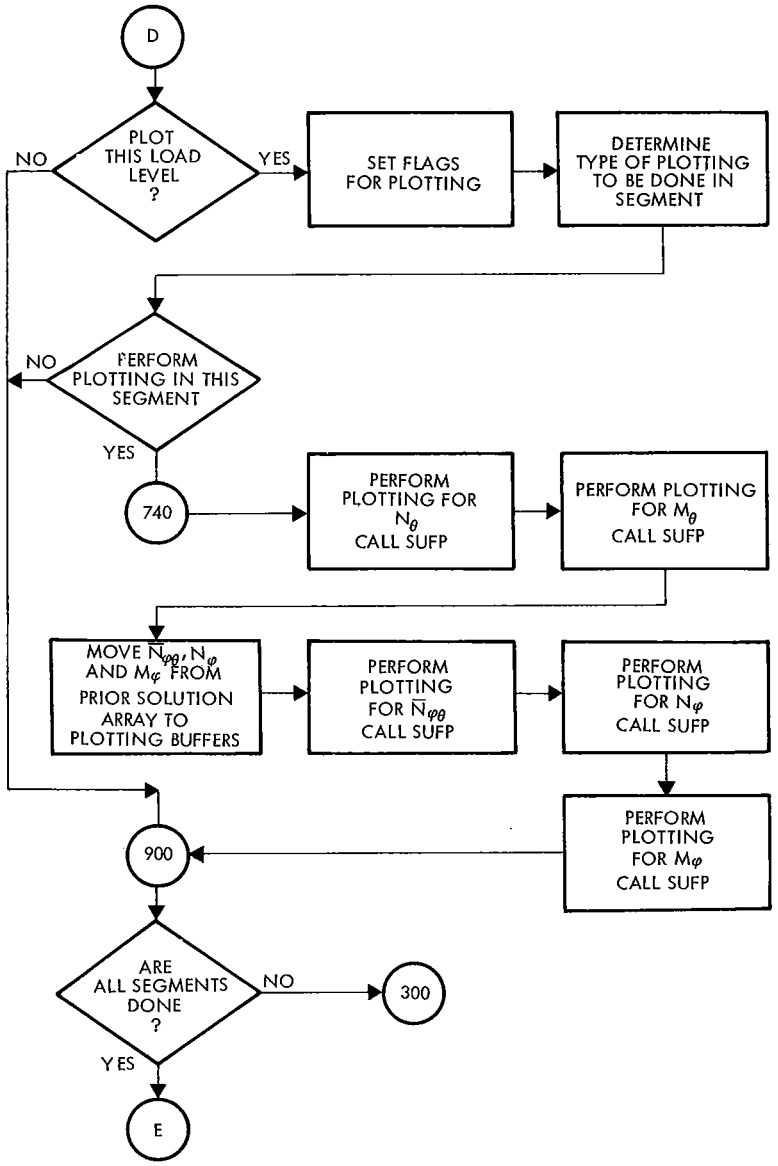


Figure 2.26. Subroutine MON6X (Continued)

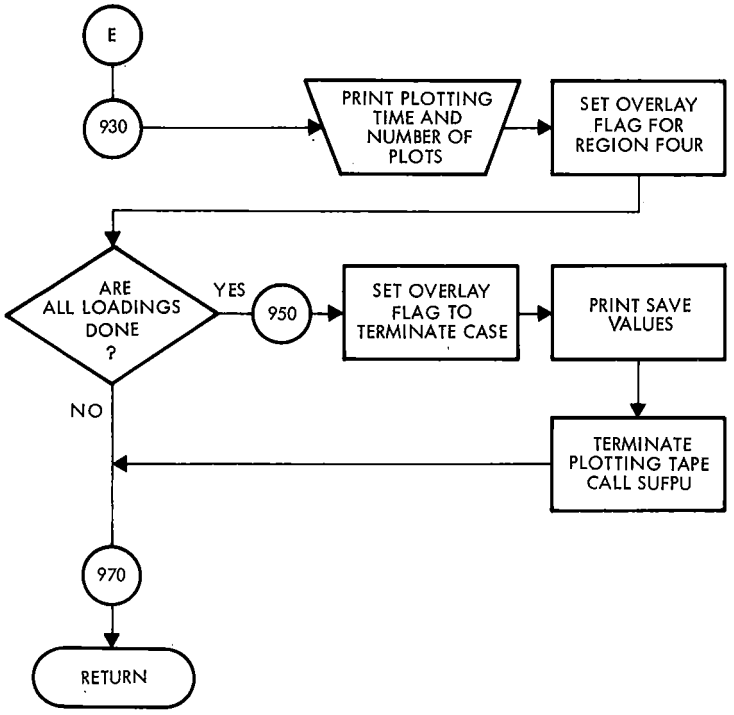


Figure 2.26. Subroutine MON6X (Continued)

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