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STRESS ANALYSIS OF A REACTOR CORE
SUPPORT STRUCTURE CONSISTING OF
TWO INTERCONNECTED MULTIREGION PLATES

by

A. H. Marchertas

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Reactor Engineering Division

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March 1968

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STRESS ANALYSIS OF A REACTOR CORE SUPPORT STRUCTURE CONSISTING OF TWO INTERCONNECTED MULTIREGION PLATES

by

A. H. Marchertas

I. INTRODUCTION

The stress analysis of a coupled axisymmetric two-plate core support structure has been described in the first part of ANL-7162. The primary purpose of this portion is the presentation of the corresponding computer program. In addition, extra analytical developments which had not been included in the first portion are given in this part. This additional analysis modifies, but in no way replaces, the previous presentation.

The additions have been introduced after sample results of a similar analysis¹ were compared with those of a similar analysis and with experimental data. Reference 1 demonstrated that under certain conditions the introduced modifications provide better agreement with experimental evidence. Modifications have thus been made to avail this improvement to the user by way of the computer program.

The finalized computer program incorporates all the variables of the core support structure as treated in the entire analysis. Logic of the computer program, listing of the FORTRAN statements, input instructions, and sample output are all given in the present text. With help of this computer program, data are obtained for comparison with the mentioned experimental results.

Since the analysis given in this presentation is a continuation of the preceding work, the same sequence of equations and figures is continued. The same nomenclature is also preserved in this portion of the report. However, new symbols are identified wherever used.

II. RIGID BEHAVIOR OF SUPPORT STRUCTURE

The analysis in the first part of ANL-7162 had assumed that the location of the neutral surface of the individual plates remains midway between its top and bottom surfaces. This assumption seems quite reasonable, provided that the flexibility of the plates is considerably greater than that of the interconnecting members. In the limiting case, when the tube flexibility approaches that of the plates, the two plates act as one and their

individual neutral surfaces approach each other. In a practical support structure, the neutral surfaces of the plates vary with location somewhere between the two extreme limits.

The change in location of the neutral surface and the resultant effect on the deformation on the overall support structure have been considered before.¹ Deformation of structure with rigid interconnecting members was superimposed with the individual bending of the plates. The direct superposition of the two effects appears proper in the case of the support structure since the expectant transverse deformations are much smaller than the thicknesses of the plates. A further indication of the veracity of the procedure is vividly demonstrated by direct comparison with experimental results. It is thus only natural to make this additional contribution of deformation available for consideration when and if such action is deemed appropriate.

In the analysis of the structure with rigid spacers, both plates are assumed to be connected by an imaginary medium which provides full continuation from one plate to the other and yet does not contribute to the resistance of deformation; the applied load is carried entirely by the plates.

This structural behavior of such a system may be likened to a one-dimensional action of a wide-flange beam in bending, where the flanges carry the brunt of the load.

$$M = M_{rA} + M_{rB} + N_r \left[L + \frac{1}{2} (h_A + h_B) \right]$$

Fig. 20. Stress Representation in Two Plates Deforming as One

The stress distribution in the bending of the two plates together is shown in Fig. 20. The distribution of radial stress across the thickness of the plate is given as

$$\sigma_r = - \frac{Ez}{1 - \nu^2} \left[\frac{d^2w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right], \quad (95)$$

where the symbols are the same as those in the first part of ANL-7162 and w pertains to the transverse deflection of the combined structure. The resulting radial bending moment represented in Fig. 20 can be expressed by the integral

$$M_r = \int_{-\delta_B - h_B}^{-\delta_B} \sigma_{rB} z \, dz + \int_{\delta_A}^{\delta_A + h_A} \sigma_{rA} z \, dz, \quad (96)$$

and the new symbols are shown in the figure. Substituting Eq. 95 into Eq. 96 and performing the indicated integrations, we obtain

$$M_r = -\frac{4D_A}{h_A^2} \left[3\delta_A^2 + 3\delta_A h_A + h_A^2 \right] \left[\frac{d^2 w}{dr^2} + \frac{\nu_A}{r} \frac{dw}{dr} \right] - \frac{4D_B}{h_B^2} \left[3\delta_B^2 + 3\delta_B h_B + h_B^2 \right] \left[\frac{d^2 w}{dr^2} + \frac{\nu_B}{r} \frac{dw}{dr} \right], \quad (97)$$

where D_A and D_B are the flexural rigidities of the top and bottom plates, respectively.

An additional condition can be had by assuming (as in the bending of beams in general) that the tension in one plate is balanced by the compression of the other.[†] This condition is mathematically expressed as

$$\int_{\delta_A}^{\delta_A + h_A} \sigma_{rA} dz = - \int_{\delta_B + h_B}^{\delta_B} \sigma_{rB} dz. \quad (98)$$

Substituting Eq. 95 with its respective subscripts into Eq. 98 and evaluating the integrals results in the expression

$$\frac{D_A}{h_A^2} (2\delta_A + h_A) \left[\frac{d^2 w}{dr^2} + \frac{\nu_A}{r} \frac{dw}{dr} \right] = \frac{D_B}{h_B^2} (2\delta_B + h_B) \left[\frac{d^2 w}{dr^2} + \frac{\nu_B}{r} \frac{dw}{dr} \right]. \quad (99)$$

In view of Eq. 99, an assumption is made that the Poisson's ratio of the two plates is nearly the same; consequently, the differentials of Eq. 99 cancel and yield

$$\frac{D_A}{h_A^2} (2\delta_A + h_A) = \frac{D_B}{h_B^2} (2\delta_B + h_B). \quad (100)$$

Equation 100, together with the identity $L = \delta_A + \delta_B$ from Fig. 20, can be solved simultaneously to yield the expressions for δ_A and δ_B . The resultant equalities become

$$\left. \begin{aligned} \delta_A &= \frac{D_B h_A^2 (2L + h_B) - D_A h_A h_B^2}{2(D_A h_B^2 + D_B h_A^2)}, \\ \delta_B &= \frac{D_A h_B^2 (2L + h_A) - D_B h_A^2 h_B}{2(D_A h_B^2 + D_B h_A^2)}. \end{aligned} \right\} \quad (101)$$

[†] Although this assumption is true in beam theory, it is not necessarily the case in the deformation of axisymmetric plates. Nevertheless, the expected discrepancy is believed to be small.

If we substitute Eqs. 101 into Eq. 97 and combine common terms, the radial moment becomes

$$M_r = -D \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right], \quad (102)$$

where

$$D = \frac{1}{(D_A h_B^2 + D_B h_A^2)^2} \left\{ D_A^3 h_B^4 + D_A^2 D_B h_B^2 \left[12L(L + h_A + h_B) + 5h_A^2 + 6h_A h_B + 4h_B^2 \right] \right. \\ \left. + D_A D_B^2 h_A^2 \left[12L(L + h_A + h_B) + 4h_A^2 + 6h_A h_B + 5h_B^2 \right] + D_B^3 h_A^4 \right\},$$

and the Poisson's ratio ν is taken to be the arithmetic average between that of the top and bottom plates.

Equation 102 has the same form as the radial-moment expression of a homogeneous plate, except for the modified flexural rigidity D . Hence, the solutions of deflection and other plate characteristics are the same as those given by Eqs. 5, 8, 9, and 14, provided the flexural rigidity is properly interchanged.

Correspondingly, the solution of the multiregion plate structure with rigid spacers is the same as that of Section V.A of the first portion of ANL-7162. Consequently, Eq. 53 represents the internal radial moments for $n = 1, 2, 3, \dots, m-1$ of the new plate.

The edge-moment expression is obtained with the help of Eqs. 48, 50, and 60, yielding

$$M_{rm} \Big|_{r_m} = \frac{\kappa}{ZE(m) + \kappa ZA(m) ZA(m-1) ZC(m-1) a_{(m-1)(m-1)}^{-1}} \left\{ ZE(m) M_{rpm} \Big|_{r_m} \right. \\ + ZA(m-1) \left[M_{P(m-1)} - M_{rpm} \Big|_{r_{m-1}} \right] - \frac{r_{m-1}}{r_m} ZG(m) \left[Q_{rm} \Big|_{r_{m-1}} - Q_{rpm} \Big|_{r_{m-1}} \right] \\ + \frac{1}{r_m} ZC(m) S_{pm} \Big|_{r_m} + ZA(m-1) \sum_{i=1}^{m-1} a_{(m-1)i}^{-1} \left[ZMPO(i) M_{P(i-1)} \right. \\ \left. + ZMPl(i) M_{Pi} + ZPO(i) P_0 + \sum_{j=1}^i ZP(i, j) P_j + ZMPS(i) \right] \Big\}, \quad (103)$$

where κ is the average of radial plate restraints of the top and bottom plates.

Thus, Eqs. 103 and 53 represent the internal moments of the support structure with rigid spacers. Once the moments are evaluated, then the constants of integration are given by Eqs. 16. Furthermore, deflection for the plate is given by Eqs. 9 and 14, provided the modified flexural rigidity is used in the calculation and the external loads are those external to the entire support structure.

The stress induced in each plate is calculated by apportioning the total radial bending moment of the structure into bending moments and membrane loads as shown in Fig. 20. The mathematical equality of the loads and moments is represented as

$$M_r = M_{rA} + M_{rB} + N_r \left[L + \frac{1}{2} (h_A + h_B) \right]. \quad (104)$$

The membrane load N_r in each plate was assumed to be the same in both plates and hence is found by integrating the stress expression of Eq. 95 over either plate. Thus,

$$N_r = \int_{\delta_A}^{\delta_A + h_A} \sigma_{rA} dz = \frac{12D_A D_B}{D_A h_B^2 + D_B h_A^2} \left[L + \frac{1}{2} (h_A + h_B) \right] \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right]. \quad (105)$$

The corresponding stresses at the upper and lower surfaces of the top plate are

$$\left. \begin{aligned} \sigma_r \Big|_{z=\delta_A + h_A} &= \frac{6D_A}{h_A^2 (D_A h_B^2 + D_B h_A^2)} \left[D_A h_B^2 + D_B h_A (2L + 2h_A + h_B) \right] \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right], \\ \sigma_r \Big|_{z=\delta_A} &= \frac{6D_A}{h_B^2 (D_A h_B^2 + D_B h_A^2)} \left[D_B h_A (2L + h_B) - D_A h_B^2 \right] \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right]. \end{aligned} \right\} \quad (106)$$

The difference between the maximum stress in the top plate and the average stress in the top plate is

$$\sigma_r \Big|_{z=\delta_A + h_A} - \frac{1}{h_A} N_r = \frac{6D_A}{h_A^2} \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right]. \quad (107)$$

Consequently, the bending moment M_{rA} of the top plate in Eq. 104 becomes

$$\begin{aligned} M_{rA} &= -\left(\frac{2}{3} h_A\right) h_A \left(\frac{6D_A}{h_A}\right) \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right] \\ &= -D_A \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right], \end{aligned} \quad (108)$$

and, similarly, the bending moment M_{rB} for the bottom plate becomes

$$M_{rB} = -D_B \left[\frac{d^2 w}{dr^2} + \frac{\nu}{r} \frac{dw}{dr} \right]. \quad (109)$$

As a result of this equivalence, the loads of the individual plates, with the help of Eq. 104, can be related to the bending moment as follows:

$$M_{rA} = \frac{D_A}{D} M_r,$$

$$M_{rB} = \frac{D_B}{D} M_r,$$

$$N_r = \frac{D - D_A - D_B}{D \left[L + \frac{1}{2} (h_A + h_B) \right]} M_r.$$

The bending and membrane stresses due to the deformation of the support structure as ascribed to in this section are related to the total bending moment. The membrane stresses and bending stresses at the surface of the plates become

$$\left. \begin{aligned} \sigma_{rbA} &= \frac{6D_A}{h_A^2 D} M_r, & \sigma_{\theta bA} &= \frac{6D_A}{h_A^2 D} M_\theta, \\ \sigma_{rbB} &= \frac{6D_B}{h_B^2 D} M_r, & \sigma_{\theta bB} &= \frac{6D_B}{h_B^2 D} M_\theta, \\ \sigma_{rmA} &= \frac{D - D_A - D_B}{h_A D \left[L + \frac{1}{2} (h_A + h_B) \right]} M_r, & \sigma_{\theta mA} &= \frac{D - D_A - D_B}{h_A D \left[L + \frac{1}{2} (h_A + h_B) \right]} M_\theta, \\ \sigma_{rmB} &= \frac{D - D_A - D_B}{h_B D \left[L + \frac{1}{2} (h_A + h_B) \right]} M_r, & \sigma_{\theta mB} &= \frac{D - D_A - D_B}{h_B D \left[L + \frac{1}{2} (h_A + h_B) \right]} M_\theta, \end{aligned} \right\} \quad (110)$$

where

$$M_\theta = -D \left[\nu \frac{d^2 w}{dr^2} + \frac{1}{r} \frac{dw}{dr} \right].$$

III. MODIFICATIONS OF PLATE-TUBE JUNCTIONS

In the foregoing analysis of the support structure, two basic types of assumptions had been made: those dealing with the elastic behavior of plates and beams, and that of the manner of connection between plates and beams. The validity of elastic behavior in plates and beams has been accepted for a long time and certainly does not need justification at this point. The major source of probable discrepancy thus lies in the connection considerations of beams and plates.

The assumption of equality between the angular deformation of the ends of the tubes and the neutral surface of the plates is reasonable when the flexibility of the tubes is relatively small as compared with that of the plates. However, when the combined flexibility of the tubes becomes appreciable, then the said assumption may no longer be satisfactory. In this case some corrective measures may be taken to bring better agreement of the structure's behavior with experimental results. Such effects as shear in the tubes and localized deformation of the plates and tubes can contribute in this respect, and are considered in Sections A and B below.

A. Shear Effects in Tubes

The analysis thus far has neglected the contribution of shear in the deformation of the tubes. However, when the length of the connecting members becomes comparable in magnitude to their lateral dimensions, then the shear effect in the tubes may contribute appreciably to the transverse deformation of the entire support structure by way of angular displacement. The angle of displacements or shear strain for a uniform beam is

$$S_s = \frac{2\tau(1+\nu)}{E}, \quad (111)$$

where τ is the maximum shear stress in the beam. For a circular cross section, this is given by

$$\tau = \frac{AQ}{3\pi I},$$

where Q is the shear load, A is the cross-sectional area, and I is the moment of inertia. Consequently, the angular displacement due to shear becomes

$$S_s = \frac{2(1+\nu) AQ}{3\pi EI}. \quad (112)$$

For a given beam of known material and uniform cross section, S_s is thus directly proportional to the magnitude of the shear load Q .

The contribution of this additional angular deformation of Eq. 112 will appear at the junction with the plates. Thus, the algebraic sum of angular deformations due to the bending and shear would always take part simultaneously. When the shear effect is added to Eqs. 64, Eqs. 64 may still be represented in the same form as follows:

$$\left. \begin{aligned} \zeta_n M_{PnA} &= AH^*(n) S_{(n+1)A} \Big|_{r_n} + AI^*(n) S_{(n+1)B} \Big|_{r_n} & (n = 1, 2, 3, \dots, m-1) \\ \zeta_n M_{PnB} &= BI^*(n) S_{(n+1)A} \Big|_{r_n} + BH^*(n) S_{(n+1)B} \Big|_{r_n} & (n = 1, 2, 3, \dots, m-1) \end{aligned} \right\} \quad (113)$$

where

$$\zeta_n = - \frac{2\pi r_n \ell_n^3}{\lambda_n E_n I_n}$$

$$AH^*(n) = AH(n) + \mu_n(\ell_n + g_{nA})[AH(n) + AI(n)],$$

$$BH^*(n) = BH(n) + \mu_n(\ell_n + g_{nA})[BH(n) + BI(n)],$$

$$AI^*(n) = AI(n) + \mu_n(\ell_n + g_{nB})[AH(n) + AI(n)],$$

and

$$BI^*(n) = BI(n) + \mu_n(\ell_n + g_{nB})[BH(n) + BI(n)].$$

The last term in the above expressions is due to the shear effect in which

$$\mu_n = - \frac{(1 + \nu_n)(d_{0n}^2 - d_{in}^2)}{\ell_n^3 + (1 + \nu_n)(d_{0n}^2 - d_{in}^2)(2\ell_n + g_{nA} + g_{nB})}$$

Thus, the use of Eqs. 113 instead of Eqs. 64 provides for the angular deviation from the condition of perpendicularity due to effect of shear in the tubes.

B. Localized Plate Deformation

When a plate is acted upon by a concentrated moment, a localized deformation results. The situation is similar to that of a transverse load-carrying beam which intersects the plane of the plate. This localized angular displacement caused by the beam may be approximated by the action of the concentrated moment acting on a plate. For a circular, simply supported plate with a concentrated moment in its center, Timoshenko and Woinowsky-Krieger² give the deflection in the plane of the moment as

$$w_\ell = \frac{M_\ell}{4\pi D} r \log_e \left(\frac{r}{a} \right), \quad (114)$$

where a is the radius of the plate, r is its radial coordinate, and M_ℓ is the applied moment. The corresponding slope S_ℓ of the curve is obtained by differentiating Eq. 114, which becomes

$$S_\ell = \frac{M_\ell}{4\pi D} \left[1 + \log_e \left(\frac{r}{a} \right) \right]. \quad (115)$$

To use Eq. 115 for the plates being intersected by the tubes, an equivalent imaginary area is assumed to be acted upon by each tube. Thus, the imaginary area (the radius of which is a) is set equal to the total plate area divided by the number of tubes being subjected to bending. This equivalence results in

$$\pi a^2 = \frac{\pi}{\lambda_n} \left[\left(\frac{r_n + r_{n+1}}{2} \right)^2 - \left(\frac{r_{n-1} + r_n}{2} \right)^2 \right],$$

and, consequently, the expression for the radius a becomes

$$a = \sqrt{\frac{1}{4\lambda_n} (r_{n+1} - r_{n-1})(2r_n + r_{n+1} + r_{n-1})}. \quad (116)$$

It is apparent from Eq. 114 that the magnitude of the slope depends on the radius at which it is evaluated. For lack of a better approximation, a radius equal to the outside radius of the intersecting tube d_0 is used here for this purpose. Hence, when all the values are substituted, Eq. 115 becomes

$$S_\ell = \frac{M_\ell}{2\pi(D_n + D_{n+1})} \left[1 + \log_e \sqrt{\frac{\lambda_n d_{0n}^2}{(r_{n+1} - r_{n-1})(2r_n + r_{n+1} + r_{n-1})}} \right]. \quad (117)$$

Consequently, the angular displacement of the plate due to the action of a tube is directly proportional to the applied moment.

Similar to the procedure of Section III.A, the additional slope given by Eq. 117 is added to the slope of the plates in bending at the junctions of the regions. When this is done, equations of the same form as Eqs. 64 result, yielding

$$\left. \begin{aligned} \zeta_n M_{PnA} &= AH^{**}(n) S_{(n+1)A} \Big|_{r_n} + AI^{**}(n) S_{(n+1)B} \Big|_{r_n} & (n = 1, 2, 3, \dots, m-1), \\ \zeta_n M_{PnB} &= BI^{**}(n) S_{(n+1)A} \Big|_{r_n} + BH^{**}(n) S_{(n+1)B} \Big|_{r_n} & (n = 1, 2, 3, \dots, m-1), \end{aligned} \right\} \quad (118)$$

where

$$AH^{**}(n) = \frac{\zeta_n \{ \zeta_n AH^*(n) + \rho_{nB} [AH^*(n) BH^*(n) - AI^*(n) BI^*(n)] \}}{\gamma_n},$$

$$BH^{**}(n) = \frac{\zeta_n \{ \zeta_n BH^*(n) + \rho_{nA} [AH^*(n) BH^*(n) - AI^*(n) BI^*(n)] \}}{\gamma_n},$$

$$AI^{**}(n) = \frac{\zeta_n^2 AI^*(n)}{\gamma_n},$$

$$BI^{**}(n) = \frac{\zeta_n^2 BI^*(n)}{\gamma_n},$$

in which

$$\begin{aligned} \gamma_n = & -\zeta_n^2 + \zeta_n [AH^*(n) \rho_{nA} + BH^*(n) \rho_{nB}] \\ & + \rho_{nA} \rho_{nB} [AH^*(n) BH^*(n) - AI^*(n) BI^*(n)], \end{aligned}$$

and

$$\rho_n = -\frac{\lambda_n}{4\pi r_n (D_n - D_{n+1})} \left[1 + \log_e \sqrt{\frac{\lambda_n d_{on}^2}{(r_{n+1} - r_{n-1})(2r_n + r_{n+1} + r_{n-1})}} \right].$$

The expressions of $AH^{**}(n)$, $BH^{**}(n)$, $AI^{**}(n)$, and $BI^{**}(n)$ are in place of the corresponding ones in Eqs. 64 or those in Eqs. 113, depending on whether the contribution of shear in the tubes to the angular displacement of the junction is or is not to be included.

IV. DESCRIPTION OF COMPUTER PROGRAM

The computer program has been written in CDC-3600 FORTRAN language and operates on a 64K CDC-3600 computer under the SCOPE monitor. Symbols used in the program correspond closely with those of the connected analysis. The program is decomposed into several portions; namely, the main program (called MAIN) and several subroutines (PLATE, PLATTER, EDGE 1, EDGE 2, and SHELLOUT). Use is also made of an additional subroutine program from the computer library called MATINV, a standard program for most computers.

Logic of the computer program is illustrated by the flow charts for each subroutine in Appendix A. Since the MATINV subroutine is regarded as a standard for most computers, it is not given in this presentation. The FORTRAN statements are listed in Appendix C, where the subroutines are appropriately designated. Input instructions to the program are outlined in Appendix B. A sample output pertaining to one of the previously described test structures is given in Appendix D.

Certain restrictions have been put on the computer program; although the analysis has been presented in terms of any number of regions in the plate, there is a finite number to which the computer program must be limited. In this respect, a limit of 25 regions per plate has been set. This number is somewhat arbitrary but depends on the storage room of the computer. For example, solution of such a 25-region problem with two intermediate shells would amount to solving a 77-by-77 matrix. With the need for additional storage, a bank of 32K was found to be insufficient to accommodate the program.

Other restrictions that have been incorporated into the program deal with the number of terms in the series representing the loading functions of each plate region and every shell. This maximum number of terms for all series has been set to four. Another such restriction was purely for the convenience of the computer programmer. Thus, the outermost radius $R(M)$ of each plate was set equal to the last radius $RR(NRR)$ for which resultant information is requested.

The restrictions mentioned above should not be regarded as limiting the use of the method. This would necessarily be a limit on the computer's storage. Thus, if the computer is small, then compromises are in order. However, if the computer capacity is sufficiently large, then the so-called restrictions can be easily circumvented by changing the appropriate portions of the program.

As an illustration of the time involved, the solution of the problem (the output of which is given in Appendix D) was recorded to be 9 sec. Since no numerical approximations are involved in the program, the solutions are exact (based on the initial assumptions) and consume little computer time.

V. COMPARISON WITH EXPERIMENTAL RESULTS

The computer program having been completed, calculations could be done and results compared with previously available experimental data. The first set of experimental results had been reported in ANL-6781.³ These were results derived from a simplified stainless steel model of a

support structure consisting of two plates and interconnected with rods. The other set of experimental data had been obtained from a similar plastic model of the structure, which had been reported in ANL-7145.¹ The analytical results are compared with both sets of experimental data in Sections A and B below.

A. Steel Model

The results obtained from the stainless steel model pertained to tests with certain transverse loads acting on top of every interconnecting rod. All concentrated loads were the same in magnitude, as was the restraint at the edges of both plates. Several sets of loading were applied on the structure, and the results of deflections at the edges of the plates and strains (radial and tangential) in several locations were obtained. Since results for all sets of loadings were qualitatively similar, data for only one loading (500 lb per rod) are presented for illustration.

The experimental measurements of deflection at the edge of the plates were used to determine the degree of edge restraint. Thus, matching this deflection at the edge of the plates with those obtained from analysis resulted in the establishment of the proper edge restraint (k) for the solution. Once the restraint at the edge of the plates had been established, direct comparison of the strain (or corresponding stress) on the surface of the plates could be made.

The matched deflection at the edge is shown with the experimental results in Fig. 21. There is a slight difference between the analytical results for the value of k between results with and without modifications in the plate-tube junctions.

Deflection results are compared in Fig. 22. Differences are illustrated in results for just bending effects and those including the effects introduced by all the other contributions. Figures 23 and 24 give the radial

Fig. 21. Matched Deflections at the Edges

Fig. 22. Differences due to Modifications in Plate-tube Junctions

Fig. 23. Radial Stresses for Upper and Lower Surfaces of Top Plate

Fig. 24. Radial Stresses for Upper and Lower Surfaces of Bottom Plate

stresses for the upper and lower surfaces of the top plate and the corresponding stresses for the bottom plate, respectively. Figures 25 and 26 show the same distribution for tangential stresses.

Fig. 25. Tangential Stresses for Upper and Lower Surfaces of Top Plate

Fig. 26. Tangential Stresses for Upper and Lower Surfaces of Bottom Plate

B. Plastic Model

The second set of experimental results derives from varied plastic model tests. These models were made up of two plastic plates, 10.5 in. in diameter, separated by a number of spacers. Four variations of the model were used: two lengths of spacers (2.004 and 0.374 in. long), and two sets of distances between spacers (2 and 4 in.). In addition, two types of loads were applied to all models: a central transverse load of 1 lb and a uniformly distributed load of 0.1 psi on the surface of one plate of the structure. In all the models, hexagonal spacer distribution was maintained. Simple supports were used in all cases.

Two sets of data were taken for each test and are shown in Table I of ANL-7145, central deflection of the model and strain of the spacer located 8 in. from the center. Table I of this report presents the same experimental data together with the corresponding computer results.

Analytical results of maximum deflection are presented, both where the spacers are taken to be perpendicular to the planes of the plates, and where the junctions have been modified by the additions presented in this report. The introduced modification of the plate-rod junctions definitely improves the agreement.

TABLE I. Comparison of Analytical and Experimental Results of the Plastic Model

Type of Load	Length of Rod, in.	Hexagonal Spacing between Rods, in.	Deflection at Center of Plates, 10^{-3} in.					Experimental Results	Corrected Strain, ϵ , on a Rod 8 in. from Center, 10^{-6} in./in.	
			Analytical Results						Analytical	Experimental
			w_1	w_2^a	w_2^b	w_2^c	w^d			
Uniform	2.004	2	0.37	14.4	14.9	16.2	16.6	20.2	511	530
Uniform	2.004	4	0.37	46.8	48.3	49.3	49.7	62.0	1043	1445
Uniform	0.374	2	5.72	3.00	5.62	6.99	12.7	16.8	232	235
Uniform	0.374	4	5.72	11.12	20.5	22.0	27.7	39.0	808	1047
Concentrated	2.004	2	0.027	1.62	1.67	1.78	1.81	2.04	28.1	27
Concentrated	2.004	4	0.027	4.17	4.28	4.35	4.38	5.14	94.2	84.4
Concentrated	0.374	2	0.414	0.516	0.808	0.959	1.37	1.51	12.1	11.6
Concentrated	0.374	4	0.414	1.55	2.30	2.43	2.84	3.36	46.4	53.6

Uniform--Uniform pressure of 0.1 lb/in.² on bottom plate of model.

Concentrated--Central concentrated load of 1 lb on top plate.

w_1 --Rigid model deformation.

w_2 --Regular bending solution.

w --Total deflection to both effects.

^dNo restraints at the junctions.

^bTube shear included.

^cTube shear and plate distortion included.

^d $w = w_1 + w_2$ with tube shear and plate distortion included.

VI. CONCLUDING REMARKS

The new additions of the analysis found in this portion of the report have been appended to the main body of previously begun computer program. This resulted in complications that could have been avoided if these additions had been available at the beginning. Other complexities are also apparent in the overall construction, which could stand some simplifications. Notwithstanding the shortcomings, and although the methods used may not be the most efficient, the final computer program is, however, a working program.

Although the main function of the computer program has been fulfilled, a 100% assurance of all operations is practically impossible because of the great number of variables involved. A sincere attempt has been made to remove all discrepancies; many times a judgment as to "reasonable" and "unreasonable" had to be contended with, because the true answer was either unknown or impossible to check with hand calculations.

In the process of debugging the program, numerous special procedures had to be devised for checking the validity of certain operations, all the more because the computer was also used to check analytical portions of the analysis. It is unimportant to enumerate all the tests used in debugging; suffice it to say that some of these tests validated certain initial assumptions made in the analysis. For example, to check the validity of the superposition procedure of the analysis, the area of a uniform plate was arbitrarily subdivided into many concentric annular areas. Thus, the

computer was "fooled" in solving a plane circular-plate problem by way of the complex operation of the computer program. These results then could be compared (and were found to correspond) with solutions of known simple elastic-plate problems.

The validity of elastic analysis of plates and beams has been proven before and generally accepted. This is not to imply that results predicted by elastic analysis would perfectly agree with those derived from experiment. Manufacturing defects and experimental methods, linked with deviations in material properties, would certainly provide discrepancies from the predictions. It would be futile, however, to attempt to speculate on how much of the total deviation would be due to this effect. Whatever the apportioning of discrepancies may be, it would be reasonable to expect that the greatest portion of this would reflect other assumptions used in the overall analysis. The most prominent unknowns are located within the action of the plate-tube junctions. Although the analysis of plate-tube junctions has been modified in this report in an attempt to provide better agreement with experiment, this analysis is certainly not the complete or the final answer to this problem. The true solution of this complex plate-tube interaction would undoubtedly be the result of extensive experimental studies coupled with a reasonable analytical approach. Thus, the introduced modifications may have to be contended with as long as no more extensive experimental results are available.

Whatever the shortcomings of the analysis may be, it nevertheless provides a convenient tool for the designer. The computer program makes the analysis of support structures very simple. Design variables can be changed arbitrarily, and their effect can be observed in the output.

APPENDIX A

Flow Charts

Fig. A.1. Flow Chart for Main Program (MAIN)

Fig. A.2. Flow Chart for Subroutine PLATE

Fig. A.3. Flow Chart for Subroutine PLATTER

Fig. A.4. Flow Chart for Subroutine EDGE 1

Fig. A.5. Flow Chart for Subroutine EDGE 2

Fig. A.6. Flow Chart for Subroutine SHELLOUT

APPENDIX B

Input Instructions

CARD SEQUENCE	NO. OF CARDS	FORMAT	INPUT QUANTITY	COMMENTS
1	1	(5I6)	M = total no. of regions per plate $NEDGE = \begin{cases} 1 & \text{for EDGE 1 condition} \\ 2 & \text{for EDGE 2 condition} \end{cases}$ $NSHELL = \begin{cases} 0 & \text{if there are no intermediate shells} \\ \neq 0 & \text{if intermediate shells are present} \end{cases}$ NRR = no. of plate radii at which results are to be printed $NPRINT = \begin{cases} 0 & \text{for input and final results to be printed} \\ \neq 0 & \text{for additional output to be printed also} \end{cases}$ $NRIGID = \begin{cases} 0 & \text{for tube ends } \perp \text{ to neutral surface of plate} \\ 1 & \text{for effect of tube shear to be included into junctions} \\ 2 & \text{for effect of tube shear and local plate deformation to be included into plate-tube junctions} \end{cases}$	
2	1	(6E12.0)	KA = bending edge-restraint for upper plate if $NEDGE = 1$, or ring width at edge of upper plate if $NEDGE = 2$ KB = bending edge-restraint for lower plate if $NEDGE = 1$, or ring width at edge of lower plate if $NEDGE = 2$ $KAPA$ = radial edge-restraint of upper plate $KAPB$ = radial edge-restraint of lower plate	
3	at least 1	(6E12.0)	$RR(i), i = 1, \dots, NRR$ = plate radii at which results are to be printed	
4	1	(6E12.0)	$DTUBEIC$ = inner diameter of center tube $DTUBEOC$ = outer diameter of center tube $ETUBEC$ = modulus of elasticity of center tube $LENGTHC$ = length of center tube	
5	1/region-1	(I3,E9.0,5E12.0)	i = no. of plate region (beginning with the centermost) $R(i)$ = outside radius of region $NTUBE(i)$ = no. of tubes in the i^{th} ring of tubes $LENGTH(i)$ = length of tubes $DTUBEI(i)$ = inner diameter of tubes $DTUBEØ(i)$ = outer diameter of tubes $ETUBE(i)$ = modulus of elasticity of tubes	Consecutive region cards may be omitted and magnitudes set = values of previous region if $NTUBE(i) \geq 1,000,000$ (put 1 in left-most portion of field)
6	1	(6E12.0)	$PØU = P_{OU}$ concentrated central load on top plate	
7	1/region-1	(I12,5E12.0)	i = no. of ring of tubes $PU(i) = P_U$ load per tube for top plate $MU(i) = M_U$ moment on ring of tubes for top plate	Sign of the external loads is taken to be positive when acting in the direction as shown in Fig. 2
8	1	(6E12.0)	$PØL = P_{OL}$ concentrated central load on bottom plate	
9	1/region-1	(I12,5E12.0)	i = no. of ring of tubes $PL(i) = P_L$ load per tube for bottom plate $ML(i) = M_L$ moment on ring of tubes for bottom plate	
10	1/region	(I12,5E12.0)	i = no. of plate region (beginning with the centermost) $E(i)$ = modulus of elasticity of plate region $NU(i)$ = Poisson's ratio of plate region $H(i)$ = plate thickness of region $ALPHA(i)$ = coefficient of thermal expansion of plate region	
11	1/region	(4E12.0)	$F(i), i = 1, \dots, 4$ pressure coefficients of plate region	The same set of directions is used first for the top plate, and then for the bottom plate; consecutive region cards may be omitted and magnitudes set = values of previous region if $E(i) \geq 1,000,000,000$ (put 1 in left-most portion of field.)
12	1/region	(4E12.0)	$A(i), i = 1, \dots, 4$ temperature coefficients of plate region	
13	1/region	(4E12.0)	$B(i), i = 1, \dots, 4$ temperature coefficients of plate region	
14	1	(3E12.0)	$E(i)$ = modulus of elasticity of shell at the edge $NU(i)$ = Poisson's ratio of shell at the edge $T(i)$ = thickness of shell at the edge	<u>Cards needed only if $NEDGE = 2$</u>
15	1	(4E12.0)	$G(i), i = 1, \dots, 4$ pressure coefficients of shell at the edge	The same set of directions applies first to the top shell ($i = 1$), the bottom shell ($i = 2$), and then to the central shell ($i = 3$)
16	1	(4E12.0)	$X(i), i = 1, \dots, 4$ temperature coefficients of shell at the edge	
17	1	(4E12.0)	$Y(i), i = 1, \dots, 4$ temperature coefficients of shell at the edge	
18	1	(3E12.0)	$E(i)$ = modulus of elasticity of intermediate shell $NU(i)$ = Poisson's ratio of intermediate shell $T(i)$ = thickness of intermediate shell	<u>Cards needed only if $NSHELL \neq 0$</u>
19	1	(4E12.0)	$G(i), i = 1, \dots, 4$ pressure coefficients of intermediate shell	The same set of directions applies first to the top shell ($i = 1$) and then to the bottom shell ($i = 2$)
20	1	(4E12.0)	$X(i), i = 1, \dots, 4$ temperature coefficients of intermediate shell	
21	1	(4E12.0)	$Y(i), i = 1, \dots, 4$ temperature coefficients of intermediate shell	

APPENDIX C

Listing of Computer Programs1. Computer Program for Main Program (MAIN)

C

```

COMMON/1/M,M1,M2,MD,MT,NRR,PI,KA,KB,KAPA,KAPB,R(25),RR(100),
XNSHELL,MATA(25,25),MATB(25,25),WPIA(25),WPIB(25),WPOA(25),
XWPOB(25),QPIA(25),QPIB(25),QPOA(25),QPOB(25),MRPIA(25),MRPIB(25),
XMRPOA(25),MRPOB(25),THPIA(25),THPIB(25),THPOA(25),THPOB(25),
XAPO(25),BPO(25),AMPO(25),BMPO(25),AMP1(25),BMP1(25),AMPS(25),
XBMP5(25),AP(25,25),BP(25,25),LENGTH(25),H(25,2),NPRINT
COMMON/2/LMAX,MMAX,NMAX,NRSHELL(2),AKJ(25,25),BKJ(25,25),
XAMN(25,25),BMN(25,25)
COMMON/3/ATUBE(25),ITUBE(25),NTUBE(25),ETUBE(25),ALPHA(25,2),E(25,
X2),NU(25,2),G(25,2),D(25,2),F(25,5,2),A(25,5,2),Q(25,5,2),AH(25),
XBH(25),AI(25),BI(25),AJ(25),BJ(25),AK(25),BK(25),AL(25),BL(25),
XAM(25),BM(25),AN(25),BN(25),AO(25),BO(25)
COMMON/4/POU,POL,PU(25),PL(25),MU(25),ML(25),B(77)
COMMON/5/C(77,77)
COMMON/7/AA(25),BA(25),AB(25),BB(25),AC(25),BC(25)
COMMON/9/DTUBE0(25)
COMMON/11/GGG(5,2),XXX(5,2),YYY(5,2),ESHELL(2),NUSHELL(2),NEDGE,
XTSHELL(2),ALFSHELL(2),BETA(2),RU(2),PS(2)

```

C

```

TYPE REAL KA,KB,MU,ML,LENGTH,MRPIA,MRPIB,MRPOA,KAPA,KAPB,MB,KK,
XMRPOB,MTHPIA,MTHPIB,MTHPOA,MTHPOB,MATA,MATB,LENGTHC,ITUBE,NTUBE,
XK11M21,K12M22,K13M23,K14M24,NUSHELL,ITUBEC,NYU,NU

```

C

```

DIMENSION DTUBE1(25),SUM3(25),SUM4(25),ASP(25,25),ZU(2),XC(77,77),
XBSP(25,25),ASM(25,25),BSM(25,25),ASB(25),BSB(25),ZPS(2),BX(77),
XAWP(25,25),BWP(25,25),AWM(25,25),BWM(25,25),AWB(25),BWB(25),ZS(2),
XNYU(25),CWX(2)

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C

```

1 FORMAT (12I6)
2 FORMAT (6E12.0)
3 FORMAT (112,5E12.0)
4 FORMAT (13,E9.0,5E12.0)
1111 FORMAT(1H1)
8000 FORMAT(/27X,*DATA PERTAINING TO TUBES*/3X,*-----
X-----*/3X,*NO.OF*,
X2X,*LOC.OF*,4X,*DIAMETERS*,7X,*TUBE*,5X,*MODULUS*,3X,*CROSS SECT.
X*,1X,*MOMENT OF*/3X,*TUBES*,3X,*TUBES*,2X,*INSIDE*,1X,*OUTSIDE*,
X3X,*LENGTH*,3X,*OF ELAST.*,5X,*AREA*,6X,*INERTIA*/3X,*LAMB.*,5X,
X*R*,6X,*DI*,6X,*DO*,7X,*L*,9X,*E*11X,*A*,11X,*I*)
8001 FORMAT(F7.0,F9.3,2F8.3,F9.3,3E12.4)
8005 FORMAT(/32X,*CONTROL VARIABLES*/3X,*-----
X-----*/3X,*SYMBOL*,5X,
X*VALUE*,17X,*COMMENTS*/)
8010 FORMAT(3X,*M*,8X,*=*,I4,* TOTAL NUMBER OF REGIONS PER PLATE*/3X,
X*NEDGE*,4X,*=*,I4,* 1 FOR EDGE1, =2 FOR EDGE2 CONDITIONS*/3X,
X*NSHELL =*,I4,* 0 FOR NO INTERMEDIATE SHELLS, OTHERWISE -0*/
X3X,*NRR*,6X,*=*,I4,* NUMBER OF PLATE RADII AT WHICH RESULTS ARE
XTO BE PRINTED*/3X,*NPRINT =*,I4,* 0 FOR ONLY INPUT AND FINAL R
XRESULTS TO BE PRINTED, -0 FOR*/20X,*ADDITIONAL MATERIAL*)
8015 FORMAT(/30X,*ADDITIONAL QUANTITIES*/23X,*-----
X-----*)
8020 FORMAT(24X,*KA*,8X,*KB*,7X,*KAPA*,6X,*KAPB*/F28.3,3F10.3)
8025 FORMAT(24X,*THA*,7X,*THB*,6X,*KAPA*,6X,*KAPB*/F28.3,3F10.3)
8030 FORMAT(3X,*NRIGID =*,I4,* 1 FOR DEVIATION FROM PERPENDICULARIT
XY OF THE TUBE-PLATE*/20X,*JUNCTION DUE TO SHEAR IN THE TUBES, =2 F
XOR DEVIATION DUE*/20X,*TO SHEAR IN THE TUBES AND LOCAL DEFORMATION
X OF THE PLATE,*/20X,*=0 FOR NO DEVIATION FROM PERPENDICULARITY*)

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8100 FORMAT(/25X,*EXTERNAL CONCENTRATED LOADING*/8X*-----
X-----*/10X,*LOAD*,8X,*UPPE
XR*,8X,*UPPER*,10X,*LOWER*,8X,*LOWER*/8X,*LOCATION*,6X,*LOAD*,9X,
X*MOMENT*,9X,*LOAD*,9X,*MOMENT*/11X,*R*,11X,*PU*,12X,*MU*,
X12X,*PL*,12X,*ML*)
8101 FORMAT(F15.3,4E14.4)
8105 FORMAT(/19X,*PLATE RADII AT WHICH INFORMATION IS DESIRED*/6X,*--
X-----*
X/6X,*SEQ.NO. RADIUS*,4X,*SEQ.NO. RADIUS*,4X,*SEQ.NO. RADIUS*,4X,
X*SEQ.NO. RADIUS*/9X,*K*,5X,*R(K)*,8X,*K*,5X,*R(K)*,8X,*K*,5X,
X*R(K)*,8X,*K*,5X,*R(K)*/)
8110 FORMAT(I10,F10.3,3(I8,F10.3))
8200 FORMAT(/15X,*INTERNAL LOADS AT INTERSECTION OF PLATES AND TUBES*/
X14X,*-----*/14X,
X*LOCATION AXIAL LOAD TOP MOMENT BOTTOM MOMENT*/18X,*R*,
X12X,*P*,12X,*MU*,12X,*ML*)
8205 FORMAT (F21.3,E15.4,2E14.4)
9000 FORMAT(4X,*-----*
X-----*/4X,* (I,J) MAGNITUDE (I,J) MAGNITUDE (I
X,J) MAGNITUDE (I,J) MAGNITUDE*/)
9005 FORMAT(/23X,*COEFFICIENTS OF THE COMBINED MATRIX*)
9010 FORMAT(/19X,*INVERSE COEFFICIENTS OF THE COMBINED MATRIX*)
9015 FORMAT(/38X,*AWP*)
9020 FORMAT(/38X,*BWP*)
9025 FORMAT(/38X,*AWM*)
9030 FORMAT(/38X,*BWM*)
9035 FORMAT(/38X,*AWB*)
9040 FORMAT(/38X,*BWB*)
9045 FORMAT(/16X,*COEFFICIENTS PERTAINING TO THE COMPOSITE STRUCTURE*
X/16X,*-----*)
9050 FORMAT(I6,*,*,I2,E12.4,3(I4,*,*,I2,E12.4))
9055 FORMAT(/38X,*ASP*)
9060 FORMAT(/38X,*BSP*)
9065 FORMAT(/38X,*ASM*)
9070 FORMAT(/38X,*BSM*)
9075 FORMAT(/38X,*ASB*)
9080 FORMAT(/38X,*BSB*)
9100 FORMAT(5X,*-----*
X-----*/5X,* (I) MAGNITUDE (I) MAGNITUDE (I
X) MAGNITUDE (I) MAGNITUDE*/)
9105 FORMAT(/22X,*VECTOR ELEMENTS OF THE COMBINED MATRIX*)
9150 FORMAT(I7,E14.4,3(I5,E14.4))

```

```

C
C   ATUBE=CROSS-SECTIONAL TUBE AREA
C   DTUBEI=INSIDE TUBE DIAMETER (C ON END OF NAME INDICATES CENTER)
C   DTUBEO=OUTSIDE TUBE DIAMETER
C   ETUBE=MODULUS OF ELASTICITY OF TUBE
C   ITUBE=MOMENT OF INERTIA OF TUBE
C   LENGTH=LENGTH OF TUBES
C   MU(ML)=MOMENT FOR TOP(BOTTOM) REGION
C   NEGE=TYPE OF EDGE CONDITION (1 OR 2)
C   NTUBE=NUMBER OF TUBES/REGION
C   POU(POL)=PRESSURE AT CENTER OF TOP(BOTTOM) PLATE
C   PU(PL)=PRESSURE ON TOP(BOTTOM) REGION
C   R=RADIUS OF REGION
C   ESHELL=MODULUS OF ELASTICITY FOR SHELL
C   NUSHELL=POISSONS RATIO FOR SHELL
C   TSHELL=THICKNESS OF SHELL
C   NRSHELL=NUMBER OF REGION WHERE SHELL IS LOCATED
C   NSHELL=PRESENCE OF SHELL (NON-ZERO IF SHELL IS PRESENT)

```

```

C
99 CONTINUE
PRINT 1111
C
READ 1, M, NEDGE, NSHELL, NRR, NPRINT, NRIGID
IF (EOF, 60) 999, 2000
2000 CONTINUE
READ 2, KA, KB, KAPA, KAPB
READ 2, (RR(I), I=1, NRR)
C
LMAX=MMAX=NMAX=4
PI=3.14159265
R(M)=RR(NRR)
M1=M-1
M2=M-2
M32=3*M-2
MD=2*M
MT=3*M
MP1=M+1
MT2=MT-2
MD1=MD-1
MDP1=MD+1
MT1=MT-1
C
READ 2, DTUBEIC, DTUBEOC, ETUBEC, LENGTHC
DO 114 NR=1, M1
READ 4, NR, R(NR), NTUBE(NR), LENGTH(NR), DTUBEI(NR), DTUBEO(NR),
XETUBE(NR)
114 CONTINUE
READ 2, POU
DO 120 NR=1, M1
READ 3, NR, PU(NR), MU(NR)
120 CONTINUE
READ 2, POL
DO 130 NR=1, M1
READ 3, NR, PL(NR), ML(NR)
130 CONTINUE
C
IF (RR(1).EQ.0) RR(1)=0.00000001
DO 115 K=2, M
IF (NTUBE(K).GE.1000000) 112, 115
112 CONTINUE
NTUBE(K)=NTUBE(K-1)
LENGTH(K)=LENGTH(K-1)
DTUBEI(K)=DTUBEI(K-1)
DTUBEO(K)=DTUBEO(K-1)
ETUBE(K)=ETUBE(K-1)
115 CONTINUE
IF (DTUBEOC.EQ.0) DTUBEOC=.0000001
IF (ETUBEC.EQ.0) ETUBEC=.0000001
DO 117 I=1, M
IF (NTUBE(I).EQ.0) NTUBE(I)=.0000001
IF (ETUBE(I).EQ.0) ETUBE(I)=.0000001
IF (DTUBEO(I).EQ.0) DTUBEO(I)=.0000001
117 CONTINUE
ATUBEC=PI*(DTUBEOC**2-DTUBEIC**2)/4.
ITUBEC=PI*(DTUBEOC**4-DTUBEIC**4)/64.
DO 116 I=1, M
ATUBE(I)=PI*(DTUBEO(I)**2-DTUBEI(I)**2)/4.
ITUBE(I)=PI*(DTUBEO(I)**4-DTUBEI(I)**4)/64.

```

```

116 CONTINUE
DO 119 K=2,M
IF(PU(K).GE.1000000) 118,119
118 CONTINUE
PU(K)=PU(K-1)
MU(K)=MU(K-1)
119 CONTINUE
DO 129 K=2,M
IF(PL(K).GE.1000000) 128,129
128 CONTINUE
PL(K)=PL(K-1)
ML(K)=ML(K-1)
129 CONTINUE
C
XM=0.
XN=1.
PRINT 8005
PRINT 8010, M,NEDGE,NSHELL,NRR,NPRINT
PRINT 8030, NRIGID
PRINT 8015
IF(NEDGE.EQ.1) PRINT 8020, KA,KB,KAPA,KAPB
IF(NEDGE.EQ.2) PRINT 8025, KA,KB,KAPA,KAPB
PRINT 8105
PRINT 8110, (K,RR(K),K=1,NRR)
PRINT 8000
PRINT 8001, XN,XM,DTUBEIC,DTUBEOC,LENGTHC,ETUBEC,ATUBEC,ITUBEC
PRINT 8001, (NTUBE(I),R(I),DTUBEI(I),DTUBEO(I),LENGTH(I),
XETUBE(I),ATUBE(I),ITUBE(I), I=1,M1)
PRINT 8100
PRINT 8101, (XM,POU,XM,POL,XM)
PRINT 8101, (R(I),PU(I),MU(I),PL(I),ML(I),I=1,M1)
C
DO 135 K=1,M1
PU(K)=PU(K)*NTUBE(K)/(2.*PI*R(K))
PL(K)=PL(K)*NTUBE(K)/(2.*PI*R(K))
135 CONTINUE
C
CALL PLATE(1)
C
CALL PLATE(2)
C
C
C -----
C MAKE COMPUTATIONS FOR DEFLECTION CONDITIONS
C -----
C
MX=3*M+2
DO 98 I=1,MX
DO 97 J=1,MX
C(I,J)=0.
97 CONTINUE
B(I)=0.
98 CONTINUE
DO 360 N=2,M
NP1=N+1
NM1=N-1
NM2=N-2
AWB(N)=BWB(N)=0.
AWP(N,1)=BWP(N,1)=AWM(N,M-1)=BWM(N,M-1)=AWM(N,M)=BWM(N,M)=0.
CB1=CB2=CB3=CB4=CB5=CB6=0.
DO 260 J=1,M1
AWP(N,J+1)=BWP(N,J+1)=0.

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```

260 CONTINUE
DO 265 I=1,M
AWM(N,I)=BWM(N,I)=0.
265 CONTINUE
DO 310 K=N,M
CB1=CB1+WPIA(K)-WPOA(K)+AJ(K)*MRPIA(K)-AK(K)*MRPOA(K)
CB2=CB2+WPIB(K)-WPOB(K)+BJ(K)*MRPIB(K)-BK(K)*MRPOB(K)
K1=K-1
DO 270 J=1,K1
CB3=CB3+R(J)*AL(K)*(QPOA(J)-QPIA(J+1))
CB4=CB4+R(J)*BL(K)*(QPOB(J)-QPIB(J+1))
270 CONTINUE
SUM1=SUM2=0.
DO 275 I=1,M1
SUM1=SUM1+AKJ(I,K)*APO(I)
SUM2=SUM2+BKJ(I,K)*BPO(I)
CB5=CB5+AKJ(I,K)*AMPS(I)
CB6=CB6+BKJ(I,K)*BMPS(I)
275 CONTINUE
AWP(N,1)=AWP(N,1)+SUM1-AL(K)/(2.*PI)
BWP(N,1)=BWP(N,1)+SUM2-BL(K)/(2.*PI)
DO 285 J=1,NM1
SUM3(J)=SUM4(J)=0.
DO 280 I=J,M1
SUM3(J)=SUM3(J)+AKJ(I,K)*AP(I,J)
SUM4(J)=SUM4(J)+BKJ(I,K)*BP(I,J)
280 CONTINUE
AWP(N,J+1)=AWP(N,J+1)+SUM3(J)-R(J)*AL(K)
BWP(N,J+1)=BWP(N,J+1)+SUM4(J)-R(J)*BL(K)
285 CONTINUE
DO 295 J=N,M1
SUM3(J)=SUM4(J)=0.
DO 290 I=J,M1
SUM3(J)=SUM3(J)+AKJ(I,K)*AP(I,J)
SUM4(J)=SUM4(J)+BKJ(I,K)*BP(I,J)
290 CONTINUE
AWP(N,J+1)=AWP(N,J+1)+SUM3(J)
BWP(N,J+1)=BWP(N,J+1)+SUM4(J)
295 CONTINUE
DO 300 I=1,NM2
AWM(N,I)=AWM(N,I)+AKJ(I+1,K)*AMPO(I+1)+AKJ(I,K)*AMP1(I)
BWM(N,I)=BWM(N,I)+BKJ(I+1,K)*BMPO(I+1)+BKJ(I,K)*BMP1(I)
300 CONTINUE
DO 305 I=NM1,M2
AWM(N,I)=AWM(N,I)+AKJ(I+1,K)*AMPO(I+1)+AKJ(I,K)*AMP1(I)
BWM(N,I)=BWM(N,I)+BKJ(I+1,K)*BMPO(I+1)+BKJ(I,K)*BMP1(I)
305 CONTINUE
AWM(N,M-1)=AWM(N,M-1)+AKJ(M-1,K)*AMP1(M-1)
BWM(N,M-1)=BWM(N,M-1)+BKJ(M-1,K)*BMP1(M-1)
AWM(N,M)=AWM(N,M)-AA(M)*AC(M-1)*AKJ(M-1,K)
BWM(N,M)=BWM(N,M)-BA(M)*BC(M-1)*BKJ(M-1,K)
310 CONTINUE
DO 313 J=N,M1
SUM3(J)=SUM4(J)=0.
DO 311 K=J,M1
SUM3(J)=SUM3(J)+AL(K+1)
SUM4(J)=SUM4(J)+BL(K+1)
311 CONTINUE
AWP(N,J+1)=AWP(N,J+1)-R(J)*SUM3(J)
BWP(N,J+1)=BWP(N,J+1)-R(J)*SUM4(J)

```



```

313 CONTINUE
DO 315 I=NM1,M2
  AWM(N,I)=AWM(N,I)-AJ(I+1)
  BWM(N,I)=BWM(N,I)-BJ(I+1)
315 CONTINUE
  AWM(N,M-1)=AWM(N,M-1)-AJ(M)
  BWM(N,M-1)=BWM(N,M-1)-BJ(M)
  AWM(N,M)=AWM(N,M)+AK(M)
  BWM(N,M)=BWM(N,M)+BK(M)
  AWB(N)=CB1+CB3+CB5
  BWB(N)=CB2+CB4+CB6
360 CONTINUE
C
  SUM1=SUM2=0.
  CB1=CB2=0.
  DO 365 I=1,M1
    SUM1=SUM1+MATA(1,I)*APO(I)*AK(1)
    SUM2=SUM2+MATB(1,I)*BPO(I)*BK(1)
    CB1=CB1+MATA(1,I)*AMPS(I)
    CB2=CB2+MATB(1,I)*BMPS(I)
365 CONTINUE
  DO 370 J=1,M1
    SUM3(J)=SUM4(J)=0.
    DO 370 I=J,M1
      SUM3(J)=SUM3(J)+MATA(1,I)*AP(I,J)*AK(1)
      SUM4(J)=SUM4(J)+MATB(1,I)*BP(I,J)*BK(1)
370 CONTINUE
  AWP(1,1)=AWP(2,1)+SUM1-AL(1)/(2.*PI)
  BWP(1,1)=BWP(2,1)+SUM2-BL(1)/(2.*PI)
  DO 375 J=1,M1
    AWP(1,J+1)=AWP(2,J+1)+SUM3(J)
    BWP(1,J+1)=BWP(2,J+1)+SUM4(J)
375 CONTINUE
  DO 380 I=1,M2
    AWM(1,I)=AWM(2,I)+AK(1)*(MATA(1,I+1)*AMPO(I+1)+MATA(1,I)*AMP1(I))
    BWM(1,I)=BWM(2,I)+BK(1)*(MATB(1,I+1)*BMPO(I+1)+MATB(1,I)*BMP1(I))
380 CONTINUE
  AWM(1,M-1)=AWM(2,M-1)+AK(1)*MATA(1,M-1)*AMP1(M-1)
  BWM(1,M-1)=BWM(2,M-1)+BK(1)*MATB(1,M-1)*BMP1(M-1)
  AWM(1,M)=AWM(2,M)-AA(M)*AC(M-1)*AK(1)*MATA(1,M-1)
  BWM(1,M)=BWM(2,M)-BA(M)*BC(M-1)*BK(1)*MATB(1,M-1)
  AWB(1)=AWB(2)+AK(1)*CB1-AK(1)*MRPOA(1)-WPOA(1)+WPIA(1)
  BWB(1)=BWB(2)+BK(1)*CB2-BK(1)*MRPOB(1)-WPOB(1)+WPIB(1)
C
  EXTRA=LENGTHC/(ETUBEC*ATUBEC)
  DO 395 N=1,M
    C(N,1)=AWP(N,1)+BWP(N,1)
    CB1=AWP(N,1)*POU+BWP(N,1)*POL
    CB2=0.
    DO 385 J=1,M1
      C(N,J+1)=AWP(N,J+1)+BWP(N,J+1)
      CB2=CB2+AWP(N,J+1)*PU(J)+BWP(N,J+1)*PL(J)
385 CONTINUE
    CR3=0.
    DO 390 I=1,M1
      C(N,M+I)=AWM(N,I)
      C(N,2*M+I)=-BWM(N,I)
      CB3=CB3+AWM(N,I)*MU(I)-BWM(N,I)*ML(I)
390 CONTINUE
    C(N,2*M)=AWM(N,M)

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```

C(N,3*M)=-BWM(N,M)
C(N,N)=C(N,N)-EXTRA
B(N)=CB1+CB2-CB3-AWB(N)+BWB(N)
EXTRA=2.*PI*LENGTH(N)*R(N)/(NTUBE(N)*ETUBE(N)*ATUBE(N))
395 CONTINUE
C
C -----
C MAKE COMPUTATIONS FOR SLOPE CONDITIONS
C -----
C
DO 400 I=1,M
ASB(I)=BSB(I)=0.
DO 400 J=1,M
ASP(I,J)=BSP(I,J)=ASM(I,J)=BSM(I,J)=0.
400 CONTINUE
DO 445 N=2,M
NP1=N+1
NM1=N-1
SUM1=SUM2=0.
CB1=CB2=CB3=CB4=0.
DO 410 I=1,M1
SUM1=SUM1+AMN(I,N)*APO(I)
SUM2=SUM2+BMN(I,N)*BPO(I)
CB1=CB1+AMN(I,N)*AMPS(I)
CB2=CB2+BMN(I,N)*BMPS(I)
410 CONTINUE
ASP(N,1)=SUM1+AO(N)/(2.*PI)
BSP(N,1)=SUM2+BO(N)/(2.*PI)
DO 420 J=1,NM1
SUM3(J)=SUM4(J)=0.
DO 415 I=J,M1
SUM3(J)=SUM3(J)+AMN(I,N)*AP(I,J)
SUM4(J)=SUM4(J)+BMN(I,N)*BP(I,J)
415 CONTINUE
CB3=CB3+R(J)*(QPOA(J)-QPIA(J+1))
CB4=CB4+R(J)*(QPOB(J)-QPIB(J+1))
ASP(N,J+1)=SUM3(J)+R(J)*AO(N)
BSP(N,J+1)=SUM4(J)+R(J)*BO(N)
420 CONTINUE
DO 430 J=N,M1
SUM3(J)=SUM4(J)=0.
DO 425 I=J,M1
SUM3(J)=SUM3(J)+AMN(I,N)*AP(I,J)
SUM4(J)=SUM4(J)+BMN(I,N)*BP(I,J)
425 CONTINUE
ASP(N,J+1)=SUM3(J)
BSP(N,J+1)=SUM4(J)
430 CONTINUE
DO 440 I=1,M2
ASM(N,I)=AMN(I+1,N)*AMPO(I+1)+AMN(I,N)*AMP1(I)
BSM(N,I)=BMN(I+1,N)*BMPO(I+1)+BMN(I,N)*BMP1(I)
440 CONTINUE
ASM(N,M-1)=AMN(M-1,N)*AMP1(M-1)
BSM(N,M-1)=BMN(M-1,N)*BMP1(M-1)
ASM(N,M)=-AA(M)*AC(M-1)*AMN(M-1,N)
BSM(N,M)=-BA(M)*BC(M-1)*BMN(M-1,N)
ASM(N,N-1)=ASM(N,N-1)+AM(N)
BSM(N,N-1)=BSM(N,N-1)+BM(N)
ASB(N)=CB1-AO(N)*CB3-AM(N)*MRPIA(N)+AN(N)*MRPOA(N)+THPIA(N)
BSB(N)=CB2-BO(N)*CB4-BM(N)*MRPIB(N)+BN(N)*MRPOB(N)+THPIB(N)

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```

445 CONTINUE
   ASM(M,M)=ASM(M,M)-AN(M)
   BSM(M,M)=BSM(M,M)-BN(M)
C
   DO 465 N=1,M1
   EXTRA=2.*PI*R(N)*LENGTH(N)**3/(NTUBE(N)*ETUBE(N)*ITUBE(N))
C
C   CONTRIBUTION OF SHEAR IN TUBES
C
   IF(NRIGID.LT.1) GO TO 448
   NYU(N)=(NU(N,1)+NU(N,2))/2.
   C1=(1.+NYU(N))*(DTUBEQ(N)**2-DTUBEI(N)**2)/(LENGTH(N)**3
X+(1.+NYU(N))*(DTUBEQ(N)**2-DTUBEI(N)**2)*(2.*LENGTH(N)
X+(H(N,1)+H(N+1,1)+H(N,2)+H(N+1,2))/2.))
   CWX(1)=C1*(LENGTH(N)+(H(N,1)+H(N+1,1))/2.)
   CWX(2)=C1*(LENGTH(N)+(H(N,2)+H(N+1,2))/2.)
   C2=AH(N)+AI(N)
   C3=BI(N)+BH(N)
   AH(N)=AH(N)-CWX(1)*C2
   AI(N)=AI(N)-CWX(2)*C2
   BI(N)=BI(N)-CWX(1)*C3
   BH(N)=BH(N)-CWX(2)*C3
C
C   CONTRIBUTION OF PLATE DISTORTION
C
   IF(NRIGID.NE.2) GO TO 448
   ARGO=DTUBEQ(N)*SQRTF(NTUBE(N)/((R(N+1)-R(N-1))*(2.*R(N)+R(N+1)
X+R(N-1))))
   DO 447 K=1,2
   CWX(K)=NTUBE(N)*((LOGF(ARGO)+1.)/(4.*PI*R(N)*(D(N,K)+D(N+1,K))))
447 CONTINUE
   CWY=AH(N)*BH(N)-AI(N)*BI(N)
   CWZ=EXTRA*(EXTRA-AH(N)*CWX(1)-BH(N)*CWX(2))+CWX(1)*CWX(2)*CWY
   AH(N)=EXTRA*AH(N)-CWX(2)*CWY
   AI(N)=EXTRA*AI(N)
   BH(N)=EXTRA*BH(N)-CWX(1)*CWY
   BI(N)=EXTRA*BI(N)
   EXTRA=CWZ
C
448 CONTINUE
   CB1=CB2=CB3=CB4=CB5=CB6=0.
   C(M+N,1)=AH(N)*ASP(N+1,1)-AI(N)*BSP(N+1,1)
   C(2*M+N-1,1)=BI(N)*ASP(N+1,1)-BH(N)*BSP(N+1,1)
   CB1=AH(N)*ASP(N+1,1)*POU-AI(N)*BSP(N+1,1)*POL
   CB2=BI(N)*ASP(N+1,1)*POU-BH(N)*BSP(N+1,1)*POL
   DO 450 J=1,M1
   C(M+N,J+1)=AH(N)*ASP(N+1,J+1)-AI(N)*BSP(N+1,J+1)
   C(2*M+N-1,J+1)=BI(N)*ASP(N+1,J+1)-BH(N)*BSP(N+1,J+1)
   CB3=CB3+AH(N)*ASP(N+1,J+1)*PU(J)-AI(N)*BSP(N+1,J+1)*PL(J)
   CB4=CB4+BI(N)*ASP(N+1,J+1)*PU(J)-BH(N)*BSP(N+1,J+1)*PL(J)
450 CONTINUE
   DO 455 I=1,M
   C(M+N,M+I)=AH(N)*ASM(N+1,I)
   C(M+N,2*M+I)=AI(N)*BSM(N+1,I)
   C(2*M+N-1,M+I)=BI(N)*ASM(N+1,I)
   C(2*M+N-1,2*M+I)=BH(N)*BSM(N+1,I)
455 CONTINUE
   C(M+N,M+N)=C(M+N,M+N)+EXTRA
   C(2*M+N-1,2*M+N)=C(2*M+N-1,2*M+N)+EXTRA
   DO 460 I=1,M1

```

```

      CB5=CB5+AH(N)*ASM(N+1,I)*MU(I)+AI(N)*BSM(N+1,I)*ML(I)
      CB6=CB6+BI(N)*ASM(N+1,I)*MU(I)+BH(N)*BSM(N+1,I)*ML(I)
460  CONTINUE
      B(M+N)=CB1+CB3-CB5-AH(N)*ASB(N+1)-AI(N)*BSB(N+1)
      B(2*M+N-1)=CB2+CB4-CB6-BI(N)*ASB(N+1)-BH(N)*BSB(N+1)
465  CONTINUE

```

C

```

      IF(NPRINT.EQ.0) GO TO 470
      PRINT 9045
      PRINT 9015
      PRINT 9000
      PRINT 9050, ((I,J,AWP(I,J),J=1,M),I=1,M)
      PRINT 9020
      PRINT 9000
      PRINT 9050, ((I,J,BWP(I,J),J=1,M),I=1,M)
      PRINT 9025
      PRINT 9000
      PRINT 9050, ((I,J,AWM(I,J),J=1,M),I=1,M)
      PRINT 9030
      PRINT 9000
      PRINT 9050, ((I,J,BWM(I,J),J=1,M),I=1,M)
      PRINT 9035
      PRINT 9100
      PRINT 9150, (I,AWB(I),I=1,M)
      PRINT 9040
      PRINT 9100
      PRINT 9150, (I,BWB(I),I=1,M)
      PRINT 9055
      PRINT 9000
      PRINT 9050, ((I,J,ASP(I,J),J=1,M),I=1,M)
      PRINT 9060
      PRINT 9000
      PRINT 9050, ((I,J,BSP(I,J),J=1,M),I=1,M)
      PRINT 9065
      PRINT 9000
      PRINT 9050, ((I,J,ASM(I,J),J=1,M),I=1,M)
      PRINT 9070
      PRINT 9000
      PRINT 9050, ((I,J,BSM(I,J),J=1,M),I=1,M)
      PRINT 9075
      PRINT 9100
      PRINT 9150, (I,ASB(I),I=1,M)
      PRINT 9080
      PRINT 9100
      PRINT 9150, (I,BSB(I),I=1,M)
470  CONTINUE

```

C

C

C

C

C

```

-----
ADD ONTO MATRIX AND VECTOR FOR GENERAL EDGE CONDITION
-----

```

C

C

C

C

C

C

C

C

C

```

      IF(NEDGE.EQ.1) 490,491
490  CALL EDGE1
      GO TO 492
491  CALL EDGE2
492  CONTINUE
      MX=MT

```

```

C
C
C -----
C ADD SHELL CONTRIBUTION
C -----
C
C IF(NSHELL.EQ.0) GO TO 605
C NRP=4
C
C DO 501 I=1,2
C READ 3, NRSHELL(I),ESHELL(I),NUSHELL(I),TSHELL(I),ALFSHELL(I)
C IF(TSHELL(I).EQ.0) TSHELL(I)=0.00001
C READ 2, (GGG(J,I),J=1,NRP)
C READ 2, (XXX(J,I),J=1,NRP)
C READ 2, (YYY(J,I),J=1,NRP)
C
C N=NRSHELL(I)
C BETA(I)=SQRTF(SQRTF(3.*(1.-NUSHELL(I))/(R(N)**2*TSHELL(I)**2)))
C DD=ESHELL(I)*TSHELL(I)**3/(12.*(1.-NUSHELL(I)**2))
C ZPS(I)=1./(BETA(I)*G(N,I)+2.)
C CZ1=0.25/BETA(I)**4
C CZ2=ESHELL(I)*ALPHA(N,I)*TSHELL(I)/R(N)
C CZ3=R(N)/12.*TSHELL(I)/(1.-NUSHELL(I))
C RU(I)=CZ1*(GGG(1,I)+CZ2*(XXX(1,I)-2.*CZ3*YYY(3,I)))/DD
C PS(I)=CZ1*(GGG(2,I)+CZ2*(XXX(2,I)-6.*CZ3*YYY(4,I)))/DD
C PM=-CZ1*(2.*GGG(3,I)+2.*CZ2*XXX(3,I))
C PQ=-CZ1*(6.*GGG(4,I)+6.*CZ2*XXX(4,I))
C ZS(I)=2.*BETA(I)*ZPS(I)*(RU(I)+PS(I)/BETA(I)
C X-PM/(2.*DD*BETA(I)**2))
C ZU(I)=ZPS(I)/(DD*BETA(I))
501 CONTINUE
C AS=ZS(1)
C AU=ZU(1)
C BS=ZS(2)
C BU=ZU(2)
C MX=MT+2
C DO 520 I=1,MX
C C(3*M+1,I)=0.
C C(3*M+2,I)=0.
520 CONTINUE
C
C N=NRSHELL(1)
C C(3*M+1,1)=ASP(N+1,1)
C DO 525 J=1,M1
C C(3*M+1,J+1)=ASP(N+1,J+1)
525 CONTINUE
C DO 530 I=1,M
C C(3*M+1,M+I)=ASM(N+1,I)
530 CONTINUE
C C(3*M+1,3*M+1)=ASM(N+1,N)+AU
C DO 535 K=1,MT
C C(K,3*M+1)=C(K,M+N)
535 CONTINUE
C C(M+N,3*M+1)=C(M+N,M+N)-(2.*PI*R(N)*LENGTH(N)**3)
C X/(NTUBE(N)*ETUBE(N)*ITUBE(N))
C CA1=0.
C DO 540 J=1,M1
C CA1=CA1+C(3*M+1,J+1)*PU(J)-C(3*M+1,M+J)*MU(J)
540 CONTINUE
C B(3*M+1)=C(3*M+1,1)*POU+CA1-ASB(N+1)-AS
C
C N=NRSHELL(2)

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```

      C(3*M+2,1)=-BSP(N+1,1)
      DO 575 J=1,M1
      C(3*M+2,J+1)=-BSP(N+1,J+1)
575  CONTINUE
      DO 580 I=1,M
      C(3*M+2,2*M+I)=BSM(N+1,I)
580  CONTINUE
      C(3*M+2,3*M+2)=BSM(N+1,N)+BU
      DO 585 K=1,MT
      C(K,3*M+2)=C(K,2*M+N)
585  CONTINUE
      C(2*M+N-1,3*M+2)=C(2*M+N-1,2*M+N)-(2.*PI*R(N)
      X*LENGTH(N)**3)/(NTUBE(N)*ETUBE(N)*ITUBE(N))
      CB1=0.
      DO 590 J=1,M1
      CB1=CB1-C(3*M+2,J+1)*PL(J)-C(3*M+2,2*M+J)*ML(J)
590  CONTINUE
      R(3*M+2)=-C(3*M+2,1)*POL+CB1-BSB(N+1)+BS
605  CONTINUE
      DO 610 I=1,MX
      DO 610 J=1,MX
      XC(I,J)=C(I,J)
610  CONTINUE
C
      IF(NPRINT.EQ.0) GO TO 611
      PRINT 9005
      PRINT 9000
      PRINT 9050, ((I,J,C(I,J)),J=1,MX),I=1,MX)
      PRINT 9105
      PRINT 9100
      PRINT 9150, (I,B(I),I=1,MX)
611  CONTINUE
C
      CALL MATINV (C,MX,B,1,DETERM,77)
C
      PRINT 8200
      PRINT 8205, XM,R(1),XM,XM
      DO 612 I=1,M1
      MPI=M+I
      MDPI=MD+I
612  PRINT 8205, R(I),B(I+1),B(MPI),B(MDPI)
      PRINT 8205, R(M),XM,B(MD),B(MT)
C
      DO 620 I=1,MX
      CX=0.
      DO 615 J=1,MX
      CX=CX+XC(I,J)*B(J)
615  CONTINUE
      BX(I)=CX
620  CONTINUE
C
      CALL PLATTER
C
      GO TO 99
999  CONTINUE
      END

```

2. Computer Program for Subroutine PLATE

```

C
C      * C MATRIX AND B VECTOR IN THIS SUBROUTINE ARE NOT = THOSE IN MAIN
C      ROUTINE
C
COMMON/1/M,M1,M2,MD,MT,NRR,PI,KA,KB,KAPA,KAPB,R(25),RR(100),
XNSHELL,MAT(25,25,2),WPI(25,2),WPO(25,2),QPI(25,2),QPO(25,2),
XMRPI(25,2),MRPO(25,2),THPI(25,2),THPO(25,2),ZPO(25,2),ZMPO(25,2),
XZMPI(25,2),ZMPS(25,2),ZP(25,25,2),LENGTH(25),H(25,2),NPRINT
COMMON/2/LMAX,MMAX,NMAX,NRSHELL(2),ZKJ(25,25,2),ZMN(25,25,2)
COMMON/3/ATUBE(25),ITUBE(25),NTUBE(25),ETUBE(25),ALPHA(25,2),E(25,
X2),NU(25,2),G(25,2),D(25,2),F(25,5,2),A(25,5,2),B(25,5,2),ZH(25,2)
X,ZI(25,2),ZJ(25,2),ZK(25,2),ZL(25,2),ZM(25,2),ZN(25,2),ZO(25,2)
COMMON/4/POU,POL,PU(25),PL(25),MU(25),ML(25),BBB(77)
COMMON/6/ZD(25,2),ZE(25,2),ZF(25,2),ZG(25,2)
COMMON/7/ZA(25,2),ZB(25,2),ZC(25,2)
COMMON/8/CB1(25),CB2(25),CB3(25),CB4(25),PQ(25),WB(26),WC(25),
XMPQ(25),MB(25),DB(25)
C
TYPE REAL NU,NUSHELL,MRPI,MRPO,MTHPI,MTHPO,MAT,LENGTH,MTHET20,
XMR1,MR11,MR10,MTHET1,MTHET11,MTHET10,MR2,MR21,MR20,MTHET2,MTHET21,
XKAP,MQ,MPI,MPO,MB,KAPA,KAPB
C
DIMENSION C(25,25),MTHPI(25,2),MTHPO(25,2),SUM(25),MQ(25),WI(25),
XDDD(25),QN(25),QXI(25),QXO(25),SPI(25),SPO(25),MPI(25),SB(25),
XVV(25),V(25)
C
2 FORMAT (6E12.0)
3 FORMAT (11E12.0)
4 FORMAT (6E19.3)
8200 FORMAT(3X,-----
X-----*/3X,*REGION*,2X,*OUTSIDE*,4X,*PLATE*,4X,
X*MODULUS OF*,3X,*POISSONS*,3X,*EXPANSION*,4X,*FLEXURAL*/12X,
X*RADIUS*,2X,*THICKNESS*,2X,*ELASTICITY*,4X,*RATIO*,4X,*COEFFICIENT
X*,3X,*RIGIDITY*/14X,*R*,9X,*H*,10X,*E*,11X,*NU*,8X,*ALPHA*,9X,*D*)
8201 FORMAT(17,F11.3,F9.3,E14.4,3E12.4)
8202 FORMAT(///22X,*PROPERTIES OF THE TOP PLATE REGIONS*/22X,=====
X=====**//30X,*PHYSICAL CONSTANTS*)
8203 FORMAT(///21X,*PROPERTIES OF THE BOTTOM PLATE REGIONS*/21X,=====
X=====**//30X,*PHYSICAL CONSTANTS*)
8300 FORMAT(//30X,*LOADING PARAMETERS*)
8302 FORMAT(113,4X,*F*,4E12.3/17X,*A*,4E12.3/17X,*B*,4E12.3/)
8304 FORMAT(17X,-----*/9X,
X*REGION*,19X,*TERMS OF THE SERIES*/25X,*1*,11X,*2*,11X,
X*3*,11X,*4*)
8305 FORMAT(/34X,*TOP PLATE*)
8307 FORMAT(/34X,*BOTTOM PLATE*)
8401 FORMAT(18X,*WPI*,10X,*WPO*,10X,*SPI*,10X,*SPO*,9X,*MRPI*)
8402 FORMAT(/17X,*MRPO*,8X,*MTHPI*,8X,*MTHPO*,10X,*QPI*,10X,*QPO*)
8403 FORMAT(18,E16.4,4E13.4)
8500 FORMAT(//30X,*ADDITIONAL QUANTITIES*/18X,-----
X-----*/4X,*REGION*)
8501 FORMAT(/18X,*ZA*,11X,*ZB*,11X,*ZC*,11X,*ZD*,11X,*ZE*)
8502 FORMAT(/18X,*ZF*,11X,*ZG*,11X,*ZH*,11X,*ZI*,11X,*ZJ*)
8503 FORMAT(/18X,*ZK*,11X,*ZL*,11X,*ZM*,11X,*ZN*,11X,*ZO*)
8507 FORMAT(/22X,*ZPO*,10X,*ZMPO*,10X,*ZMPI*,10X,*ZMPS*)
8509 FORMAT(18,E20.4,3E14.4)
9000 FORMAT(4X,-----
X-----*/4X,* (I,J) MAGNITUDE (I,J) MAGNITUDE (I
X,J) MAGNITUDE (I,J) MAGNITUDE*/)

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```

9005 FORMAT(/38X,*ZP*)
9010 FORMAT(/38X,*ZKJ*)
9015 FORMAT(/38X,*ZMN*)
9020 FORMAT(/23X,*COEFFICIENTS OF THE BENDING MATRIX*)
9025 FORMAT(/19X,*INVERSE COEFFICIENTS OF THE BENDING MATRIX*)
9050 FORMAT(I6,*,*,I2,E12.4,3(I4,*,*,I2,E12.4))

```

```

C
C      A=TEMPERATURE COEFFICIENTS FOR REGION
C      ALPHA=LINEAR THERMAL EXPANSION OF REGION
C      E=MODULUS OF ELASTICITY OF REGION
C      F=PRESSURE COEFFICIENTS FOR REGION
C      H=THICKNESS OF REGION
C      NU=POISSONS RATIO FOR REGION
C      R=RADIUS OF REGION
C
      IF(NP.EQ.1)100,111
100 CONTINUE
      DO 105 NP=1,2
C
      DO 103 NR=1,M
      READ 3, NR,E(NR,NP),NU(NR,NP),H(NR,NP),ALPHA(NR,NP)
      READ 2, (F(NR,J,NP),J=1,LMAX)
      READ 2, (A(NR,J,NP),J=1,MMAX)
      READ 2, (B(NR,J,NP),J=1,NMAX)
103 CONTINUE
C
      DO 99 K=2,M
      IF(E(K,NP).GE.1000000000) 98,99
98 CONTINUE
      E(K,NP)=E(K-1,NP)
      NU(K,NP)=NU(K-1,NP)
      H(K,NP)=H(K-1,NP)
      ALPHA(K,NP)=ALPHA(K-1,NP)
      DO 99 J=1,MMAX
      F(K,J,NP)=F(K-1,J,NP)
      A(K,J,NP)=A(K-1,J,NP)
      B(K,J,NP)=B(K-1,J,NP)
99 CONTINUE
      DO 110 I=1,M1
      G(I,NP)=(H(I,NP)+H(I+1,NP))/2.
      D(I,NP)=(E(I,NP)*H(I,NP)**3)/(12.*(1.-NU(I,NP)**2))
110 CONTINUE
      G(M,NP)=H(M,NP)
      D(M,NP)=(E(M,NP)*H(M,NP)**3)/(12.*(1.-NU(M,NP)**2))
105 CONTINUE
      NP=1
111 CONTINUE
C
      IF(NP.EQ.1) 70,75
70 PRINT 8202
      GO TO 77
75 PRINT 8203
77 CONTINUE
      PRINT 8200
      PRINT 8201, (I,R(I),H(I,NP),E(I,NP),NU(I,NP),ALPHA(I,NP),
      XD(I,NP),I=1,M)
      PRINT 8300
      PRINT 8304
      PRINT 8302, (I,(F(I,J,NP),J=1,4),(A(I,J,NP),J=1,4),
      X(B(I,J,NP),J=1,4),I=1,M)

```


C

```

DO 125 I=1,M
  IF(I-1) 112,112,114
112 RRR=0.
  GO TO 116.
114 RRR=R(I-1)
116 CONTINUE
  W1I=W10=THET1I=THET10=MR1I=MR10=MTHET1I=MTHET10=QI=Q0=0.
  W2I=W20=THET2I=THET20=MR2I=MR20=MTHET2I=MTHET20=0.
  DO 120 L=1,LMAX
    W1=F(I,L,NP)/((L+1.)*2*(L+3.)*2)
    W1I=W1*RRR**2*(L+3.)+W1I
    W10=W1*R(I)**2*(L+3.)+W10
    THET1=F(I,L,NP)/((L+1.)*2*(L+3.))
    THET1I=THET1*RRR**2*(L+2.)+THET1I
    THET10=THET1*R(I)**2*(L+2.)+THET10
    MR1=(L+2.+NU(I,NP))*F(I,L,NP)/((L+1.)*2*(L+3.))
    MR1I=MR1*RRR**2*(L+1.)+MR1I
    MR10=MR1*R(I)**2*(L+1.)+MR10
    MTHET1=(1.+NU(I,NP)*(L+2.))*F(I,L,NP)/((L+1.)*2*(L+3.))
    MTHET1I=MTHET1*RRR**2*(L+1.)+MTHET1I
    MTHET10=MTHET1*R(I)**2*(L+1.)+MTHET10
    Q=F(I,L,NP)/(L+1.)
    QI=Q*RRR**2*L+QI
    Q0=Q*R(I)**2*L+Q0
120 CONTINUE
    DO 121 N=1,MMAX
      W2=A(I,N,NP)/(N+1.)*2
      W2I=W2*RRR**2*(N+1.)+W2I
      W20=W2*R(I)**2*(N+1.)+W20
      THET2=A(I,N,NP)/(N+1.)
      THET2I=THET2*RRR**2*N+THET2I
      THET20=THET2*R(I)**2*N+THET20
      IF(N-1) 121,121,123
123 MR2=A(I,N,NP)/(N+1.)
      MR2I=MR2*RRR**2*(N-1)+MR2I
      MR20=MR2*R(I)**2*(N-1)+MR20
      MTHET2=N*A(I,N,NP)/(N+1.)
      MTHET2I=MTHET2*RRR**2*(N-1)+MTHET2I
      MTHET20=MTHET2*R(I)**2*(N-1)+MTHET20
121 CONTINUE
      FAC=ALPHA(I,NP)*(1.+NU(I,NP))/(2.*H(I,NP))
      FACT=FAC*(1.-NU(I,NP))*D(I,NP)
      WPI(I,NP)=W1I/D(I,NP)-FAC*W2I
      WPO(I,NP)=W10/D(I,NP)-FAC*W20
      THPI(I,NP)=THET1I/D(I,NP)-FAC*THET2I
      THPO(I,NP)=THET10/D(I,NP)-FAC*THET20
      MRPI(I,NP)=-MR1I-FACT*MR2I
      MRPO(I,NP)=-MR10-FACT*MR20
      MTHPI(I,NP)=-MTHET1I-FACT*MTHET2I
      MTHPO(I,NP)=-MTHET10-FACT*MTHET20
      QPI(I,NP)=QI
      QPO(I,NP)=Q0

```

C

```

  IF(NP.EQ.2) GO TO 124
  WI(I)=WO(I)=SPI(I)=SPO(I)=MPI(I)=MPO(I)=QXI(I)=QX0(I)=0.
  VV(I)=(NU(I,1)+NU(I,2))/2.
  V(I)=VV(I)
  DDD(I)=(D(I,1)**3*H(I,2)**4+D(I,1)**2*D(I,2)*H(I,2)**2
  X*(12.*LENGTH(I)*(LENGTH(I)+H(I,1)+H(I,2))+5.*H(I,1)**2
  X+6.*H(I,1)*H(I,2)+4.*H(I,2)**2)+D(I,1)*D(I,2)**2*H(I,1)**2

```

```

X*(12.*LENGTH(I)*(LENGTH(I)+H(I,1)+H(I,2))+4.*H(I,1)**2
X+6.*H(I,1)*H(I,2)+5.*H(I,2)**2)+D(I,2)**3*H(I,1)**4)
X/(D(I,1)*H(I,2)**2+D(I,2)*H(I,1)**2)**2
DB(I)=DCD(I)
124 CONTINUE
WI(I)=WI(I)+W1I/DB(I)
WO(I)=WO(I)+W1O/DB(I)
SPI(I)=SPI(I)+THET1I/DB(I)
SPO(I)=SPO(I)+THET1O/DB(I)
MPI(I)=MPI(I)-MR1I
MPO(I)=MPO(I)-MR1O
QXI(I)=QXI(I)+QI
QXO(I)=QXO(I)+QO
125 CONTINUE
C
KEY=0
IF(NP.EQ.1) GO TO 132
DO 131 I=1,M
DDD(I)=DB(I)
VV(I)=V(I)
131 CONTINUE
GO TO 134
132 CONTINUE
DO 133 I=1,M
DDD(I)=D(I,NP)
VV(I)=NU(I,NP)
133 CONTINUE
134 CONTINUE
DO 130 I=1,M
IF(I-1) 128,128,129
128 TEMPOR=0.
TEMP2=0.
GO TO 127
129 TEMPOR=R(I-1)
TEMP2=LOGF(R(I-1)/R(I))
127 ZA(I,NP)=2.*K(I)**2
ZB(I,NP)=DDD(I)*(1.-VV(I)**2)*(R(I)**2-TEMPOR**2)
X*DDD(I+1)*(1.-VV(I+1)**2)*(R(I+1)**2-R(I)**2)/R(I)
ZC(I,NP)=DDD(I)*(1.-VV(I)**2)*(R(I)**2-TEMPOR**2)
ZD(I,NP)=(1.+VV(I))*R(I)**2+(1.-VV(I))*TEMPOR**2
ZE(I,NP)=(1.-VV(I))*R(I)**2+(1.+VV(I))*TEMPOR**2
ZF(I,NP)=TEMPOR*((1.-VV(I))*(R(I)**2-TEMPOR**2)
X-2.*(1.+VV(I))*R(I)**2*TEMP2)/2.
ZG(I,NP)=R(I)*((1.-VV(I))*(R(I)**2-TEMPOR**2)
X-2.*(1.+VV(I))*TEMPOR**2*TEMP2)/2.
ZH(I,NP)=4.*LENGTH(I)**2+6.*LENGTH(I)*G(I,NP)+3.*G(I,NP)**2
ZI(I,NP)=2.*LENGTH(I)**2+3.*LENGTH(I)*(G(I,1)+G(I,2))+
X3.*G(I,1)*G(I,2)
ZJ(I,NP)=TEMPOR*ZF(I,NP)/ZC(I,NP)
ZK(I,NP)=R(I)*ZG(I,NP)/ZC(I,NP)
ZL(I,NP)=(13.+VV(I))*(1.-VV(I))*(R(I)**2-TEMPOR**2)**2
X+4.*(1.+VV(I))**2*R(I)**2*TEMPOR**2*TEMP2**2)/(8.*ZC(I,NP))
ZM(I,NP)=TEMPOR*ZD(I,NP)/ZC(I,NP)
ZN(I,NP)=2.*R(I)**2*TEMPOR/ZC(I,NP)
ZO(I,NP)=ZF(I,NP)/ZC(I,NP)
130 CONTINUE
ZB(M,NP)=0.
C
C
C CONSTRUCT BENDING MATRIX
C
II=2

```

```

DO 135 I=1,M
DO 135 J=1,M
135 C(I,J)=0.
C(1,1)=-ZC(2,NP)*ZE(1,NP)-ZC(1,NP)*ZD(2,NP)
C(1,2)=ZC(1,NP)*ZA(2,NP)
DO 140 I=2,M2
C(I,I-1)=ZA(I-1,NP)*ZC(I+1,NP)
C(I,I)=-ZC(I+1,NP)*ZE(I,NP)-ZC(I,NP)*ZD(I+1,NP)
C(I,I+1)=ZA(I+1,NP)*ZC(I,NP)
140 II=II+1
IF(M.LT.3) 150,145
145 CONTINUE
C(M-1,M-2)=ZA(M-2,NP)*ZC(M,NP)
C(M-1,M-1)=-ZC(M,NP)*ZE(M-1,NP)-ZC(M-1,NP)*ZD(M,NP)
150 CONTINUE
C
IF(NPRINT.EQ.0) GO TO 153
IF(KEY.EQ.0) PRINT 9020
IF(KEY.EQ.0) PRINT 9000
IF(KEY.EQ.0) PRINT 9050, ((I,J,C(I,J)),J=1,M1),I=1,M1)
153 CONTINUE
C
ZMPO(1,NP)=0.
ZMP1(1,NP)=ZC(1,NP)*ZD(2,NP)
ZPO(1,NP)=-ZC(2,NP)*ZG(1,NP)-ZC(1,NP)*ZF(2,NP)/(2.*PI*R(1))
ZP(1,1,NP)=ZC(1,NP)*ZF(2,NP)
ZMPS(1,NP)=-ZC(2,NP)*ZE(1,NP)*MRPO(1,NP)-ZC(1,NP)*(ZD(2,NP)
X*MRPI(2,NP)-ZA(2,NP)*MRPO(2,NP)+ZF(2,NP)*(QPO(1,NP)-QPI(2,NP)))
X-ZB(1,NP)*(THPO(1,NP)-THPI(2,NP))
ZMPO(M,NP)=0.
DO 160 I=2,M1
ZFACT=(ZC(I+1,NP)*ZG(I,NP)-ZC(I,NP)*ZF(I+1,NP))/R(I)
ZMPO(I,NP)=-ZC(I+1,NP)*ZA(I-1,NP)
ZMP1(I,NP)=ZC(I,NP)*ZD(I+1,NP)
ZPO(I,NP)=-ZFACT/(2.*PI)
ZP(I,I,NP)=ZC(I,NP)*ZF(I+1,NP)
J1=I-1
ZSUM=0.
DO 155 J=1,J1
ZP(I,J,NP)=-R(J)*ZFACT
155 ZSUM=ZSUM+R(J)*(QPO(J,NP)-QPI(J+1,NP))
ZSUM=ZSUM*ZFACT
ZMPS(I,NP)=ZC(I+1,NP)*ZA(I-1,NP)*MRPI(I,NP)-ZC(I+1,NP)*ZE(I,NP)
X*MRPO(I,NP)-ZC(I,NP)*ZD(I+1,NP)*MRPI(I+1,NP)+ZC(I,NP)*ZA(I+1,NP)
X*MRPO(I+1,NP)-ZB(I,NP)*(THPO(I,NP)-THPI(I+1,NP))-ZC(I,NP)
X*ZF(I+1,NP)*(QPO(I,NP)-QPI(I+1,NP))+ZSUM
160 CONTINUE
165 M1=M-1
170 CONTINUE
C
CALL MATINV (C,M1,B,0,DETERM,25)
C
DO 175 I=1,M1
DO 175 J=1,M1
175 MAT(I,J,NP)=C(I,J)
DO 180 I=1,M1
DO 180 J=1,M
ZKJ(I,J,NP)=ZK(J,NP)*MAT(J,I,NP)-ZJ(J,NP)*MAT(J-1,I,NP)
ZMN(I,J,NP)=ZM(J,NP)*MAT(J-1,I,NP)-ZN(J,NP)*MAT(J,I,NP)
ZKJ(I,M,NP)=-ZJ(M,NP)*MAT(M-1,I,NP)
ZKJ(I,1,NP)=ZK(1,NP)*MAT(1,I,NP)

```

```

      ZMN(I,M,NP)=ZM(M,NP)*MAT(M-1,I,NP)
      ZMN(I,1,NP)=-ZN(1,NP)*MAT(1,I,NP)
180  CONTINUE
      IF(NP.EQ.1) 190,183
183  IF(KEY.EQ.0) 185,190
C
C      SOLUTION RESULTING FROM RIGID SPACERS
C
185  CONTINUE
      KAP=(KAPA+KAPB)/2.
      PQO=POL-POU
      DO 200 I=1,M1
      PQ(I)=PL(I)-PU(I)
      MQ(I)=ML(I)+MU(I)
200  CONTINUE
      DO 215 I=2,M
      J1=I-1
      CM4=QN(I)=0.
      DO 210 J=1,J1
      QN(I)=QN(I)+R(J)*(PQ(J)-(QXO(J)-QXI(J+1)))
      CM4=CM4+R(J)*(QXO(J)-QXI(J+1))
210  CONTINUE
      QN(I)=-PQO/(2.*PI*R(I-1))-QN(I)/R(I-1)
      ZMPS(I,NP)=ZC(I+1,NP)*(ZA(I-1,NP)*MPI(I)-ZE(I,NP)*MPO(I))+ZC(I,NP)
      X*(ZA(I+1,NP)*MPO(I+1)-ZD(I+1,NP)*MPI(I+1)-ZF(I+1,NP)*(QXO(I)
      X-QXI(I+1)))-ZB(I,NP)*(SPO(I)-SPI(I+1))+(ZC(I+1,NP)*ZG(I,NP)
      X-ZC(I,NP)*ZF(I+1,NP))*CM4/R(I)
215  CONTINUE
      ZMPS(M,NP)=0.
      ZMPS(1,NP)=-ZC(2,NP)*ZE(1,NP)*MPO(1)+ZC(1,NP)*(ZA(2,NP)*MPO(2)
      X-ZD(2,NP)*MPI(2)-ZF(2,NP)*(QXO(1)-QXI(2)))-ZB(1,NP)*(SPO(1)
      X-SPI(2))
      CM2=0.
      DO 208 I=1,M1
      SUM(I)=0.
      DO 205 J=1,I
      SUM(I)=SUM(I)+ZP(I,J,NP)*PQ(J)
205  CONTINUE
      CM2=CM2+C(M-1,I)*(ZPO(I,NP)*PQO+SUM(I)+ZMPO(I,NP)*MQ(I-1)
      X+ZMP1(I,NP)*MQ(I)+ZMPS(I,NP))
208  CONTINUE
      MB(M)=KAP*(ZE(M,NP)*MPO(M)+ZA(M-1,NP)*(MQ(M-1)-MPI(M))+ZC(M,NP)
      X*SPO(M)/R(M)-R(M-1)*ZG(M,NP)*QN(M)/R(M)+ZA(M-1,NP)*CM2)/(ZE(M,NP)
      X+KAP*ZA(M,NP)*ZA(M-1,NP)*ZC(M-1,NP)*C(M-1,M-1))
      DO 227 N=1,M1
      MB(N)=0.
      DO 225 I=1,M1
      MB(N)=MB(N)+MAT(N,I,NP)*(ZPO(I,NP)*PQO+SUM(I)+ZMPO(I,NP)*MQ(I-1)
      X+ZMP1(I,NP)*MQ(I)+ZMPS(I,NP))
225  CONTINUE
      MB(N)=MAT(N,M-1,NP)*ZA(M,NP)*ZC(M-1,NP)*MR(M)+MB(N)
227  CONTINUE
      WB(M+1)=0.
      DO 230 N=1,M1
      K=M+1-N
      WB(K)=WB(K+1)-ZJ(K,NP)*(MB(K-1)+MQ(K-1)-MPI(K))
      X+ZK(K,NP)*(MB(K)-MPO(K))+R(K-1)*ZL(K,NP)*QN(K)+WI(K)-WO(K)
230  CONTINUE
      DO 235 N=2,M
      RA=R(N)**2-R(N-1)**2
      RB=LOGF(R(N-1)/R(N))

```

```

C1=MB(N-1)+MQ(N-1)-MPI(N)
C2=MB(N)-MPO(N)
SB(N)=ZM(N,NP)*C1-ZN(N,NP)*C2-R(N-1)*ZO(N,NP)*QN(N)+SPI(N)
CB4(N)=R(N-1)*QN(N)/(4.*DB(N))
CB3(N)=(R(N)*R(N-1))*2*(C1-C2+(1.+VV(N))*R(N-1)*RB*QN(N)/2.)
X/(DB(N)*(1.-VV(N))*RA)
CB2(N)=(R(N-1))*2*C1-R(N))*2*C2-(R(N-1)/4.)*((3.+VV(N))*RA
X-2.*(1.+VV(N))*R(N-1))*2*RB)*QN(N))/(2.*DB(N)*(1.+VV(N))*RA)
CB1(N)=-CB2(N)*R(N))*2-WO(N)+WB(N+1)
235 CONTINUE
KEY=1
GO TO 132
190 CONTINUE

```

C

```

IF(NPRINT.EQ.0) GO TO 195
PRINT 8500
PRINT 8401
PRINT 8403, (I,WPI(I,NP),WPO(I,NP),THPI(I,NP),THPO(I,NP),
XMRPI(I,NP),I=1,M)
PRINT 8402
PRINT 8403, (I,MRPO(I,NP),MTHPI(I,NP),MTHPO(I,NP),QPI(I,NP),
XQPO(I,NP),I=1,M)
PRINT 8501
PRINT 8403, (I,ZA(I,NP),ZB(I,NP),ZC(I,NP),ZD(I,NP),ZE(I,NP),I=1,M)
PRINT 8502
PRINT 8403, (I,ZF(I,NP),ZG(I,NP),ZH(I,NP),ZI(I,NP),ZJ(I,NP),I=1,M)
PRINT 8503
PRINT 8403, (I,ZK(I,NP),ZL(I,NP),ZM(I,NP),ZN(I,NP),ZO(I,NP),I=1,M)
PRINT 8507
PRINT 8509, (I,ZPO(I,NP),ZMPO(I,NP),ZMP1(I,NP),ZMPS(I,NP),I=1,M1)
PRINT 9005
PRINT 9000
PRINT 9050, ((I,J,ZP(I,J,NP),J=1,M1),I=1,M1)
PRINT 9010
PRINT 9000
PRINT 9050, ((I,J,ZKJ(I,J,NP),J=1,M),I=1,M1)
PRINT 9015
PRINT 9000
PRINT 9050, ((I,J,ZMN(I,J,NP),J=1,M),I=1,M1)
PRINT 9025
PRINT 9000
PRINT 9050, ((I,J,C(I,J),J=1,M1),I=1,M1)
195 CONTINUE

```

C

```

RETURN
END

```

3. Computer Program for Subroutine PLATTER

C

```

COMMON/1/M,M1,M2,MD,MT,NRR,PI,KA,KB,KAPA,KAPB,R(25),RR(100),
XNSHELL,MAT(25,25,2),WPI(25,2),WPO(25,2),QPI(25,2),QPO(25,2),
XMRPI(25,2),MRPO(25,2),THPI(25,2),THPO(25,2),ZPO(25,2),ZMPO(25,2),
XZMPI(25,2),ZMPS(25,2),ZP(25,25,2),LENGTH(25),H(25,2),NPRINT
COMMON/2/LMAX,MMAX,NMAX,NRSHELL(2),ZKJ(25,25,2),ZMN(25,25,2)
COMMON/3/ATUBE(25),ITUBE(25),NTUBE(25),ETUBE(25),ALPHA(25,2),E(25,
X2),NU(25,2),G(25,2),D(25,2),F(25,5,2),A(25,5,2),B(25,5,2),ZH(25,2)
X,ZI(25,2),ZJ(25,2),ZK(25,2),ZL(25,2),ZM(25,2),ZN(25,2),ZO(25,2)
COMMON/4/POU,POL,P(25),PL(25),MU(25),ML(25),888(77)
COMMON/6/ZDI(25,2),ZE(25,2),ZF(25,2),ZG(25,2)
COMMON/7/ZA(25,2),ZB(25,2),ZC(25,2)
COMMON/8/CB1(25),CB2(25),CB3(25),CB4(25),PQ(25),WB(26),WO(25),
XMPO(25),MB(25),DB(25)
COMMON/9/DTUBE0(25)
COMMON/10/XG(5),XA(5),XB(5),SE,SV,ST,SALF,RA,SC1,SC2,SC3,SC4
COMMON/11/GGG(5,2),XXX(5,2),YYY(5,2),ESHELL(2),NUSHELL(2),NEDGE,
XTSHELL(2),ALFSHELL(2),XETA(2),XU(2),XS(2)
COMMON/12/GGE(5,3),XXE(5,3),YYE(5,3),XE(3),XV(3),T(3),ALF(3),BET
X(3),XD(3),SIN,COS,SINH,COSH,RU(3),PS(3),PM(3),PUL,SALA,SALB,SALP

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C

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TYPE REAL MU,ML,NU,MAT,MZ,MRPO,MRPI,MNRN,MNRN1,KK,MM,NTUBE,ITUBE,
XLENGTH,MR1,MTHET1,MR2,MTHET2,MRNP,MTHNP,LOGA,KA,KB,MB,MQ,MPI,MPO,
XNUSHELL,KAPA,KAPB

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C

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DIMENSION QFACT(25),MNRN(25),MNRN1(25),THNRN1(25,2),WNRN1(26),
XC(50,50),BB(50),YA(25),YB(25),YC(25),S(25),SRB(100),STB(100),
XP(25),MZ(25,2),SUM3(25),W(100),SMR(100),SMT(100),UR(100),SRM(100),
XSTM(100),WC(100),THNRN(2),YD(25),C4(25),C3(25),C2(25),C1(25),
XCC1(25),CC2(25)

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C

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8205 FORMAT(///20X,*RESULTANT INFORMATION ON PLATES IN BENDING*/20X,
X*=====)
8210 FORMAT(16X,*REGULAR BENDING SOLUTION*,13X,*RIGID SPACER SOLUTION*/
X4X,*-----)
X-----*/4X,*RADIAL*,4X,*PLATE*,7X,*RADIAL*,4X,*TANGENTIAL*
X,4X,*PLATE*,6X,*RADIAL*,5X,*TANG.* /5X,*DIST.* ,4X,*DEFL.* ,7X,
X*STRESS*,6X,*STRESS*,6X,*DEFL.* ,6X,*STRESS*,5X,*STRESS*/7X,*R*,8X,
X*W*,10X,*SRB*,9X,*STB*,9X,*WR*,9X,*SRR*,8X,*STR*)
8215 FORMAT(///20X,*RESULTANT APPROXIMATE MEMBRANE SOLUTION*/
X20X,*=====)
8225 FORMAT(16X,*REGULAR BENDING SOLUTION*,13X,*RIGID SPACER SOLUTION*/
X4X,*-----)
X-----*/4X,*RADIAL*,4X,*PLATE*,7X,*RADIAL*,4X,*TANGENTIAL*,
X4X,*PLATE*,6X,*RADIAL*,5X,*TANG.* /5X,*DIST.* ,4X,*DEFL.* ,7X,
X*STRESS*,6X,*STRESS*,6X,*DEFL.* ,6X,*STRESS*,5X,*STRESS*/7X,*R*,8X,
X*U*,10X,*SRM*,9X,*STM*,9X,*UR*,9X,*SMR*,8X,*SMT*)
8230 FORMAT(///20X,*PROPERTIES AT THE JUNCTIONS OF THE REGIONS*/
X16X,*-----*/16X,
X*LOCATION DEFLECTION SLOPE RADIAL MOMENT*/18X,*R(N)*,
X9X,*W(N)*,10X,*S(N)*,9X,*MR(N)*)
8235 FORMAT (F23.3,E15.4,2E14.4)
8240 FORMAT(///29X,*CONSTANTS OF INTEGRATION*/9X,*-----)
X-----*/9X,*REGION*,8X,*C1*,
X13X,*C2*,13X,*C3*,13X,*C4*)
8245 FORMAT(I13,E16.4,3E15.4)
8303 FORMAT(///34X,*FINAL RESULTS*/16X,*-----)
X-----*)
8305 FORMAT(///36X,*TOP PLATE*)
8307 FORMAT(///34X,*BOTTOM PLATE*)

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8310 FORMAT(///23X,*COEFFICIENTS OF THE MEMBRANE MATRIX*)
8315 FORMAT(///19X,*INVERSE COEFFICIENTS OF THE MEMBRANE MATRIX*)
8320 FORMAT(///22X,*VECTOR ELEMENTS OF THE MEMBRANE MATRIX*)
8330 FORMAT(///28X,*CONSTANTS OF INTEGRATION*/22X,*-----
X-----*/22X,*REGION*,8X,*CC1*,12X,*CC2*)
8335 FORMAT(I25,E17.4,E15.4)
8510 FORMAT(F10.3,3E12.4,3E11.3)
8600 FORMAT(///15X,*RESULTS FOR TUBES SUBJECTED TO MAXIMUM BENDING STRES
XS*/15X,*-----*/
X 31X,*LOCATED AT R=*,F7.3/9X,*-----*/
X-----*/9X,*DIST.*,5X,*DEFLECTION*,8X,
X*AXIAL*,8X,*BENDING*,8X,*COMBINED*/11X,*X*,11X,*Y*,12X,*STRESS*,
X9X,*STRESS*,9X,*STRESS*)
8601 FORMAT(F14.3,4E15.4)
8700 FORMAT(///16X,*INFORMATION PERTAINING TO SHELLS AT THE EDGE*/16X,
X*=====*)
8701 FORMAT(///29X,*LOADING PARAMETERS*)
8702 FORMAT(13X,*G *,4E12.3/13X,*X *,4E12.3/13X,*Y *,4E12.3)
8703 FORMAT( /23X,*PHYSICAL CONSTANTS AND RESULTS*/10X,*-----
X-----*)
8704 FORMAT(13X,*-----*/
X22X,*1*,11X,*2*,11X,*3*,11X,*4*)
8705 FORMAT(///34X,*TOP SHELL*)
8710 FORMAT(///32X,*CENTER SHELL*)
8715 FORMAT(///32X,*BOTTOM SHELL*)
8720 FORMAT(10X,*E=*,E11.4,3X,*NU=*,F6.3,3X,*T=*,F6.3,3X,*ALPHA=*,E11.4
X/3X,*-----*/
X-----*/4X,*AXIAL*,5X,*RADIAL*,6X,*CIRCUMF.*,6X,*AXIAL*,7X,
X*CIRCUMF.*,6X,*RADIAL*/4X,*DIST.*,5X,*DISPL.*,8X,*LOAD*,3X,*MOMENT
X*,7X,*MOMENT*,7X,*SHEAR*/6X,*Z*,9X,*U*,11X,*N(T)*,9X,*M(Z)*,9X,
X*M(T)*,9X,*Q(Z)*)
8725 FORMAT(28X,*-----*/28X,*LOCATED AT R=*,F7.3)
8800 FORMAT(///15X,*INFORMATION PERTAINING TO INTERMEDIATE SHELLS*/15X,
X*=====*)
9000 FORMAT(4X,*-----*/
X-----*/4X,* (I,J) MAGNITUDE (I,J) MAGNITUDE (I
X,J) MAGNITUDE (I,J) MAGNITUDE*/)
9050 FORMAT(I6,*,*,I2,E12.4,3(I4,*,*,I2,E12.4))
9100 FORMAT(5X,*-----*/
X-----*/5X,* (I) MAGNITUDE (I) MAGNITUDE (I
X) MAGNITUDE (I) MAGNITUDE*/)
9150 FORMAT(I7,E14.4,3(I5,E14.4))
C
C -----
C COMPUTE FUNCTIONS FOR EACH REGION
C -----
C
IF(NSHELL) 100,101
100 NPL1=NRSHELL(1)
NPL2=NRSHELL(2)
MU(NPL1)=BBB(MT+1)
ML(NPL2)=BBB(MT+2)
101 CONTINUE
DO 138 NP=1,2
IF(NP.EQ.1) 1,3
1 PO=BBB(1)-POU
DO 2 J=1,M1
P(J)=BBB(J+1)-PU(J)
MZ(J,NP)=BBB(M+J)+MU(J)
2 CONTINUE
MZ(M,NP)=BBB(MD)

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      GO TO 5
3  PO=POL-BBB(1)
   DO 4 J=1,M1
     P(J)=PL(J)-BBB(J+1)
     MZ(J,NP)=BBB(MD+J)+ML(J)
4  CONTINUE
   MZ(M,NP)=BBB(MT)
5  CONTINUE

```

C

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      DO 104 N=1,M1
        MNRN(N)=0.
        FACTOR=-MAT(N,M-1,NP)*ZA(M,NP)*ZC(M-1,NP)*MZ(M,NP)
        DO 103 I=1,M1
          SUM3(I)=0.
          DO 102 J=1,I
            SUM3(I)=SUM3(I)+ZP(I,J,NP)*P(J)
102  CONTINUE
        MNRN(N)=MNRN(N)+MAT(N,I,NP)*(ZMPO(I,NP)*MZ(I-1,NP)
      X+ZMP1(I,NP)*MZ(I,NP)+ZPO(I,NP)*PO+SUM3(I)+ZMPS(I,NP))
103  CONTINUE
        MNRN(N)=MNRN(N)+FACTOR
104  CONTINUE
        MNRN(M)=MZ(M,NP)
        DO 106 N=2,M
          QFACT(N)=0.
          NM1=N-1
          DO 105 J=1,NM1
            QFACT(N)=QFACT(N)+R(J)*(P(J)-QPO(J,NP)+QPI(J+1,NP))
105  CONTINUE
          QFACT(N)=-PO/(2.*PI*R(N-1))-QFACT(N)/R(N-1)
          MNRN1(N)=MNRN(N-1)+MZ(N-1,NP)
          THNRN1(N,NP)=ZM(N,NP)*(MNRN1(N)-MRPI(N,NP))-ZN(N,NP)*(MNRN(N)
      X-MRPO(N,NP))-ZO(N,NP)*R(N-1)*QFACT(N)+THPI(N,NP)
106  CONTINUE
          THNRN(NP)=R(M)/ZC(M,NP)*(ZA(M-1,NP)*(MNRN1(M)-MRPI(M,NP))
      X-ZE(M,NP)*(MNRN(M)-MRPO(M,NP))-R(M-1)/R(M)*ZG(M,NP)
      X*QFACT(M))+THPU(M,NP)
          WNRN1(M+1)=0.
          DO 107 N=1,M1
            K=M+1-N
            WNRN1(K)=WNRN1(K+1)-ZJ(K,NP)*(MNRN1(K)-MRPI(K,NP))+ZK(K,NP)
      X*(MNRN(K)-MRPO(K,NP))+ZL(K,NP)*R(K-1)*QFACT(K)+WPI(K,NP)-WPO(K,NP)
107  CONTINUE

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C

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      DO 108 N=2,M
        DIV=D(N,NP)*(R(N)**2-R(N-1)**2)
        C4(N)=R(N-1)*QFACT(N)/(4.*D(N,NP))
        C3(N)=R(N)**2*R(N-1)**2*((MNRN1(N)-MRPI(N,NP))-(MNRN(N)-MRPO(N,NP)
      X)+R(N-1)*(1.+NU(N,NP))*LOGF(R(N-1)/R(N))*QFACT(N)/2.)
        X/((1.-NU(N,NP))*DIV)
        C2(N)=(R(N-1)**2*(MNRN1(N)-MRPI(N,NP))-R(N)**2*(MNRN(N)-MRPO(N,NP)
      X)-R(N-1)/4.*((3.+NU(N,NP))*R(N)**2-R(N-1)**2)-2.*(1.+NU(N,NP))
      X*R(N-1)**2*LOGF(R(N-1)/R(N))*QFACT(N))/(2.*(1.+NU(N,NP))*DIV)
        C1(N)=-R(N)**2*C2(N)+WNRN1(N+1)-WPO(N,NP)
108  CONTINUE

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C

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      IF(NP.EQ.1) PRINT 8205
      IF(NP.EQ.1) PRINT 8305
      IF(NP.EQ.2) PRINT 8307
      IF(NPRINT.EQ.0) GO TO 128
      PRINT 8230

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PRINT 8235, (R(N),WNRN1(N+1),THNRN1(N+1),MNRN(N),N=1,M1)
PRINT 8235, R(M),WNRN1(M+1),THNRN(NP),MNRN(M)
PRINT 8240
PRINT 8245, (N,C1(N),C2(N),C3(N),C4(N),N=2,M)
128 CONTINUE

C
C
C -----
C FIND RESULTS AT EACH DISTANCE TO BE INVESTIGATED
C -----
C

PRINT 8303
PRINT 8210

C
N=1
DO 137 K=1,NRR
120 IF(RR(K).LE.R(N)) 122,121
121 N=N+1
GO TO 120
122 IF(RR(K).EQ.R(N)) 123,124
123 KEY=2
GO TO 125
124 KEY=1
125 CONTINUE
IF(RR(K).EQ.0) 211,212
211 LOGA=LOGF(0.00001/R(N))
RRR=0.00001
GO TO 213
212 LOGA=LOGF(RR(K)/R(N))
RRR=RR(K)
213 CONTINUE
W1=R1=T1=W2=R2=T2=0.
DO 130 J=1,MMAX
W1=W1+F(N,J,NP)*RR(K)**(J+3)/((J+1.):**2*(J+3.):**2)
R1=R1+(J+2.+NU(N,NP))*F(N,J,NP)*RR(K)**(J+1)/((J+1.):**2*(J+3.))
T1=T1+(1.+NU(N,NP))*(J+2.)*F(N,J,NP)*RR(K)**(J+1)/((J+1.):**2
X*(J+3.))
130 CONTINUE
DO 131 L=1,NMAX
W2=W2+A(N,L,NP)*RR(K)**(L+1)/(L+1.):**2
R2=R2+A(N,L,NP)*RRR**(L-1)/(L+1.)
T2=T2+L*A(N,L,NP)*RRR**(L-1)/(L+1.)
131 CONTINUE
FAC=ALPHA(N,NP)*(1.+NU(N,NP))/(2.*H(N,NP))
FACT=FAC*(1.-NU(N,NP))*D(N,NP)
WNP=W1/D(N,NP)-FAC*W2
MRNP=-R1-FACT*R2
MTHNP=-T1-FACT*T2
IF(N.EQ.1) 126,129
126 CONTINUE
W(K)=-PO*((3.+NU(1,NP))*(R(1)**2-RR(K)**2)+2.*(1.+NU(1,NP))
X*RR(K)**2*LOGA)/(16.*PI*D(1,NP)*(1.+NU(1,NP)))+(R(1)**2
X-RR(K)**2)*(MNRN(1)-MRPO(1,NP))/(2.*D(1,NP)*(1.+NU(1,NP)))
X+WNP-WPO(1,NP)+WNRN1(2)
SRB(K)=6.*(PO*(1.+NU(1,NP))*LOGA/(4.*PI)
X+MNRN(1)+MRNP-MRPO(1,NP))/H(1,NP)**2
STB(K)=6.*(-PO*((1.-NU(1,NP))-(1.+NU(1,NP))*LOGA)
X/(4.*PI)+MNRN(1)+MTHNP-MRPO(1,NP))/H(1,NP)**2
GO TO 134
129 CONTINUE
W(K)=C1(N)+C2(N)*RR(K)**2+C3(N)*LOGA+C4(N)*RR(K)**2*LOGA+WNP
PR1=2.*C2(N)*(1.+NU(N,NP))

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PR2=C3(N)*(1.-NU(N,NP))/RR(K)**2
SRB(K)=6.*(-D(N,NP))*(PR1-PR2+C4(N)*((3.+NU(N,NP))
X+2.*(1.+NU(N,NP))*LOGA))+MRNP)/H(N,NP)**2
STB(K)=6.*(-D(N,NP))*(PR1+PR2+C4(N)*((1.+3.*NU(N,NP))
X+2.*(1.+NU(N,NP))*LOGA))+MTHNP)/H(N,NP)**2
134 CONTINUE
RR(1)=0.
W1=R1=T1=0.
V=(NU(N,1)+NU(N,2))/2.
DO 205 J=1,MMAX
CF=F(N,J,1)+F(N,J,2)
W1=W1+CF*RR(K)**(J+3)/((J+1.)**2*(J+3.)**2)
R1=R1+(J+2.+V)*CF*RR(K)**(J+1)/((J+1.)**2*(J+3.))
T1=T1+(1.+V*(J+2.))*CF*RR(K)**(J+1)/((J+1.)**2*(J+3.))
205 CONTINUE
WNP=W1/DB(N)
MRNP=-R1
MTHNP=-T1
IF(N.EQ.1) 250,260
250 CONTINUE
PQO=POL-POU
WC(K)=-PQO*((3.+V)*(R(1)**2-RR(K)**2)+2.*(1.+V)*RR(K)**2
X*LOGA)/(16.*PI*UB(1)*(1.+V))+R(1)**2-RR(K)**2)
X*(MB(1)-MPO(1))/(2.*DB(1)*(1.+V))+WNP-WO(1)+WB(2)
SRM(K)=(6.*D(1,NP)/DB(1))*(PQO*(1.+V)*LOGA/(4.*PI)+MB(1)+MRNP
X-MPO(1))/H(1,1)**2
STM(K)=(6.*D(1,NP)/DB(1))*(-PQO*((1.-V)-(1.+V)*LOGA)/(4.*PI)
X+MB(1)+MTHNP-MPO(1))/H(1,1)**2
GO TO 280
260 CONTINUE
WC(K)=CB1(N)+CB2(N)*RR(K)**2+CB3(N)*LOGA+CB4(N)*RR(K)**2*LOGA+WNP
PR1=2.*CB2(N)*(1.+V)
PR2=CB3(N)*(1.-V)/RR(K)**2
SRM(K)=(6.*D(N,NP)/DB(N))*(-DB(N)*(PR1-PR2+CB4(N)*((3.+V)
X+2.*(1.+V)*LOGA))+MRNP)/H(N,NP)**2
STM(K)=(6.*D(N,NP)/DB(N))*(-DB(N)*(PR1+PR2+CB4(N)*((1.+3.*V)
X+2.*(1.+V)*LOGA))+MTHNP)/H(N,NP)**2
280 CONTINUE
C
PRINT 8510, RR(K),W(K),SRB(K),STB(K),WC(K),SRM(K),STM(K)
C
IF(KEY.GT.1) 135,137
135 IF(RR(K).EQ.R(M)) 137,136
136 N=N+1
KEY=0
GO TO 125
137 CONTINUE
138 CONTINUE
C
C
C -----
C APPROXIMATE MEMBRANE CONTRIBUTION
C -----
C
PRINT 8215
C
M21=2*M-1
DO 1031 NP=1,2
DO 900 N=1,M
YA(N)=E(N,NP)/(1.-NU(N,NP))
YB(N)=E(N,NP)/(1.+NU(N,NP))
YC(N)=1./R(N)**2

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      YD(N)=(DB(N)-D(N,1)-D(N,2))/(DB(N)
      X*(LENGTH(N)+(H(N,1)+H(N,2))/2.))
900 CONTINUE
C
      IF(NP.EQ.1) PRINT 8305
      IF(NP.EQ.2) PRINT 8307
C
      DO 1000 I=1,M21
      DO 1000 J=1,M21
      C(I,J)=0.
1000 CONTINUE
      IF(NP.EQ.1) 90,91
90 KK=KAPA
      DO 93 N=1,M1
      S(N)=-2./G(N,1)/(2.*LENGTH(N)+G(N,1)+G(N,2))*(BBB(M+N)+BBB(2*M+N))
93 CONTINUE
      GO TO 92
91 KK=KAPB
      DO 94 N=1,M1
      S(N)=-S(N)*G(N,1)/G(N,2)
94 CONTINUE
92 CONTINUE
      C(1,1)=YA(1)
      C(2,1)=1.
      C(1,2)=-YA(2)
      C(2,2)=-1.
      C(1,3)=YB(2)*YC(1)
      C(2,3)=-YC(1)
      DO 1001 N=2,M1
      C(2*N-1,2*N-2)=YA(N)
      C(2*N,2*N-2)=1.
      C(2*N-1,2*N-1)=-YB(N)*YC(N)
      C(2*N,2*N-1)=YC(N)
      C(2*N-1,2*N)=-YA(N+1)
      C(2*N,2*N)=-1.
      C(2*N-1,2*N+1)=YB(N+1)*YC(N)
      C(2*N,2*N+1)=-YC(N)
1001 CONTINUE
      C(2*M-1,2*M-1)=-(1.-KK*(2.+NU(M,NP)))*YC(M)/(1.+NU(M,NP))
      C(2*M-1,2*M-2)=(1.-KK*NU(M,NP))/(1.-NU(M,NP))
C
      IF(NPRINT.EQ.0) GO TO 96
      PRINT 8310
      PRINT 9000
      PRINT 9050, ((I,J,C(I,J)),J=1,M21),I=1,M21)
96 CONTINUE
C
      CALL MATINV (C,M21,BB,0,DETERM,50)
C
      IF(NPRINT.EQ.0) GO TO 98
      PRINT 8315
      PRINT 9000
      PRINT 9050, ((I,J,C(I,J)),J=1,M21),I=1,M21)
98 CONTINUE
C
      RAD=0.
      DO 111 N=1,M1
      RSUM1=0.
      DO 110 L=1,LMAX
      RSUM1=BSUM1+B(N,L,NP)*(R(N)**(L+1)-RAD**((L+1)))/(L+1.)

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110 CONTINUE
  BB(2*N-1)=E(N,NP)*ALPHA(N,NP)*BSUM1/R(N)**2+S(N)
  BB(2*N)=- (1.+NU(N,NP))*ALPHA(N,NP)*BSUM1/R(N)**2
  RAD=R(N)
111 CONTINUE
  BSUM1=0.
  DO 112 L=1,LMAX
    BSUM1=BSUM1+B(M,L,NP)*(R(M)**(L+1)-R(M-1)**(L+1))/(L+1.)
112 CONTINUE
  BB(2*M-1)=(1.-KK*(2.+NU(M,NP)))*ALPHA(M,NP)*BSUM1/R(M)**2
C
  CC1(1)=CC2(1)=0.
  DO 113 J=1,M21
    CC1(1)=CC1(1)+C(1,J)*BB(J)
113 CONTINUE
  DO 114 N=2,M
    CC1(N)=CC2(N)=0.
    DO 114 J=1,M21
      CC1(N)=C(2*N-2,J)*BB(J)+CC1(N)
      CC2(N)=C(2*N-1,J)*BB(J)+CC2(N)
114 CONTINUE
C
  IF(NPRINT.EQ.0) GO TO 109
  PRINT 8320
  PRINT 9100
  PRINT 9150, (I,BB(I),I=1,M21)
  PRINT 8330
  PRINT 8335, (N,CC1(N),CC2(N),N=1,M)
109 CONTINUE
  PRINT 8303
  PRINT 8225
C
  N=1
  RAD=0.00000001
  DO 1030 K=1,NRR
2000 IF(RR(K).LE.R(N)) 2002,2001
2001 N=N+1
      GO TO 2000
2002 IF(RR(K).EQ.R(N)) 2003,2004
2003 KEY=2
      GO TO 2006
2004 KEY=1
      IF(RR(K).EQ.0) RR(1)=0.00001
2006 CONTINUE
      IF(NP.EQ.1) 115,116
115 CONTINUE
      SMR(K)=SRM(K)*DB(N)*YD(N)*H(N,NP)/D(N,NP)/6.
      SMT(K)=STM(K)*DB(N)*YD(N)*H(N,NP)/D(N,NP)/6.
      UR(K)=RR(K)/E(N,NP)*(SMT(K)-NU(N,NP)*SMR(K))
      GO TO 118
116 IF(RR(K).EQ.RAD) 117,118
117 CONTINUE
      SMR(K)=SMR(K)
      SMT(K)=SMT(K)
      GO TO 119
118 CONTINUE
      SMR(K)=-SMR(K)
      SMT(K)=-SMT(K)
      UR(K)=-UR(K)
119 CONTINUE
      BSUM2=BSUM3=0.

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```

DO 1025 L=1,LMAX
BSUM2=BSUM2+B(N,L,NP)*RR(K)**(L-1)
BSUM3=BSUM3+B(N,L,NP)*(RR(K)**(L+1)-RAD** (L+1))/(L+1.)
1025 CONTINUE
BSUM3=BSUM3/RR(K)**2
SRB(K)=YA(N)*CC1(N)-YB(N)*CC2(N)/RR(K)**2-E(N,NP)
X*ALPHA(N,NP)*BSUM3
STB(K)=YA(N)*CC1(N)+YB(N)*CC2(N)/RR(K)**2+E(N,NP)
X*ALPHA(N,NP)*(BSUM3-BSUM2)
W(K)=CC1(N)*RR(K)+CC2(N)/RR(K)+ALPHA(N,NP)*(1.+NU(N,NP))
X*RR(K)*BSUM3
RR(1)=0.

C
PRINT 8510, RR(K),W(K),SRB(K),STB(K),UR(K),SMR(K),SMT(K)

C
IF(KEY.GT.1) 2008,1030
2008 IF(RR(K).EQ.R(M)) 1030,2009
2009 N=N+1
RAD=R(N-1)
KEY=0
GO TO 2006
1030 CONTINUE
1031 CONTINUE

C
C
C -----
C INFORMATION PERTAINING TO TUBES
C -----
C

NX=0
TST=0.
DO 295 N=1,M1
IF(DTUBE0(N).EQ.0.0000001) GO TO 295
TEST=PI*R(N)*DTUBE0(N)*((2.*LENGTH(N)+G(N,2))*BBB(M+N)-G(N,1)
X*BBB(2*M+N))/(NTUBE(N)*ITUBE(N)*(2.*LENGTH(N)+G(N,1)+G(N,2)))
IF(ABSF(TEST).GT.TST) 290,295
290 TST=TEST
NX=N
295 CONTINUE
IF(NX.EQ.0) GO TO 340
SLPA=-THNRN1(NX+1,1)
SLPB=-THNRN1(NX+1,2)
COE=2.*PI*R(NX)/(NTUBE(NX)*ETUBE(NX)*ITUBE(NX)*(2.*LENGTH(NX)
X+G(NX,1)+G(NX,2)))
TMA=COE*((2.*LENGTH(NX)+G(NX,2))*BBB(M+NX)-G(NX,1)*BBB(2*M+NX))
TQA=2.*COE*(BBB(M+NX)+BBB(2*M+NX))
IF(LENGTH(NX).LE.1) 300,302
300 LX=10.*LENGTH(NX)
SX=LX/100.
GO TO 305
302 LX=LENGTH(NX)
SX=LX/10.
305 CONTINUE

C
PRINT 8600, R(NX)

C
X=0.
310 Y=X**3*TQA/6.-X*X*TMA/2.+X*SLPA+G(NX,1)*SLPA/2.
SA=2.*PI*R(NX)*BBB(NX+1)/(NTUBE(NX)*ATUBE(NX))
SZ=(ETUBE(NX)*DTUBE0(NX)/2.)*(X*TQA-TMA)
IF(SA.LT.0) 315,320
315 ST=SA-ABSF(SZ)

```

```

      GO TO 325
320 ST=SA+ABSF(SZ)
325 CONTINUE
C
      PRINT 8601, X,Y,SA,SZ,ST
C
      X=X+SX
      IF(X.LE.LENGTH(NX)) 310,330
330 XX=X-LENGTH(NX)
      IF(XX.GT.SX) 335,340
335 X=LENGTH(NX)
      GO TO 310
340 CONTINUE
C
C
C -----
C INFORMATION PERTAINING TO THE SHELLS AT THE EDGE
C -----
C
      IF(NEDGE.EQ.1) GO TO 555
C
      PRINT 8700
C
      RA=R(M)
      DO 550 J=1,3
      IF(T(J).EQ.0.) GO TO 550
      SE=XE(J)
      SV=XV(J)
      ST=T(J)
      SALF=ALF(J)
      DO 510 I=1,4
      XG(I)=GGE(I,J)
      XA(I)=XXE(I,J)
      XB(I)=YYE(I,J)
510 CONTINUE
C
      IF(J.EQ.1) PRINT 8705
      IF(J.EQ.2) PRINT 8710
      IF(J.EQ.3) PRINT 8715
      PRINT 8701
      PRINT 8704
      PRINT 8702, (XG(I),I=1,4),(XA(I),I=1,4),(XB(I),I=1,4)
      PRINT 8703
      PRINT 8720, SE,SV,ST,SALF
C
      IF(J-2) 515,520,525
515 SC4=-H(M,1)*THNRN(1)/2.-RU(J)
      SC3=-SC4
      SC2=SC4-(THNRN(1)+PS(J))/BET(J)
      SC1=-SC2
      ZLIM=2.*R(M)
      GO TO 530
520 SMAL=SALP+SALA*THNRN(1)+SALB*THNRN(2)
      SC1=-(SMAL-PM(J))/(2.*XD(J)*BET(J)**2)
      SC4=H(M,1)*THNRN(1)/2.-RU(J)
      DIV=SIN*COSH-COS*SINH
      SC2=(-SC1*SIN*SINH-(THNRN(1)-PS(J))/BET(J)*COS*SINH-H(M,2)
      *THNRN(2)/2.-PUL-SC4*COS*COSH)/DIV
      SC3=(SC1*SIN*SINH+(THNRN(1)-PS(J))/BET(J)*SIN*COSH+H(M,2)
      *THNRN(2)/2.+PUL+SC4*COS*COSH)/DIV
      ZLIM=LENGTH(M)
      GO TO 530

```

```

525 SC4=H(M,2)*THNRN(2)/2.-RU(J)
    SC3=-SC4
    SC2=SC4+(THNRN(2)-PS(J))/BET(J)
    SC1=-SC2
    ZLIM=2.*R(M)
530 CONTINUE
    LX=ZLIM
    SX=LX/20.
    Z=0.

```

C

```
535 CALL SHELLOUT(Z)
```

C

```

    Z=Z+SX
    IF(Z.LE.ZLIM) 535,540
540 XX=Z-ZLIM
    IF(XX.GT.SX) 545,550
545 Z=ZLIM
    GO TO 535
550 CONTINUE
555 CONTINUE

```

C

C

C

C

C

```

-----
INFORMATION PERTAINING TO THE INTERMEDIATE SHELLS
-----

```

```

    IF(NSHELL.EQ.0) GO TO 640
    DO 635 NP=1,2
    IF(TSHELL(NP).EQ.0.00001) GO TO 635
    SE=ESHELL(NP)
    SV=NUSHELL(NP)
    ST=TSHELL(NP)
    SALF=ALFSHELL(NP)
    N=NRSHELL(NP)
    RA=R(N)
    ZLIM=2.*R(N)
    DO 605 I=1,4
    XG(I)=GGG(I,NP)
    XA(I)=XXX(I,NP)
    XB(I)=YYY(I,NP)
605 CONTINUE

```

C

```

    IF(NP.EQ.1) PRINT 8800
    IF(NP.EQ.1) PRINT 8705
    IF(NP.EQ.2) PRINT 8715
    PRINT 8725, R(N)
    PRINT 8701
    PRINT 8704
    PRINT 8702, (XG(I),I=1,4),(XA(I),I=1,4),(XB(I),I=1,4)
    PRINT 8703
    PRINT 8720, SE,SV,ST,SALF

```

C

```

    IF(NP.EQ.1) GO TO 610
    SC4=-G(N,NP)*THNRN1(N+1,NP)/2.-XU(NP)
    SC2=SC4-(THNRN1(N+1,NP)+XS(NP))/XETA(NP)
    GO TO 615
610 SC4=G(N,NP)*THNRN1(N+1,NP)/2.-XU(NP)
    SC2=SC4+(THNRN1(N+1,NP)-XS(NP))/XETA(NP)
615 SC3=-SC4
    SC1=-SC2
    LX=ZLIM

```

SX=LX/20.
Z=0.

C

620 CALL SHELLOUT(Z).

C

Z=Z+SX

IF(Z.LE.ZLIM) 620,625

625 XX=Z-ZLIM

IF(XX.GT.SX) 630,635

630 Z=ZLIM

GO TO 620

635 CONTINUE

640 CONTINUE

C

RETURN
END

4. Computer Program for Subroutine EDGE 1

```

C      COMMON/1/M,M1,M2,MD,MT,NRR,PI,KA,KB,KAPA,KAPB,R(25),RR(100),
XNSHELL,MATA(25,25),MATB(25,25),WPIA(25),WPIB(25),WPOA(25),
XWPOB(25),QPIA(25),QPIB(25),QPOA(25),QPOB(25),MRPIA(25),MRPIB(25),
XMRPOA(25),MRPOB(25),THPIA(25),THPIB(25),THPOA(25),THPOB(25),
XAPG(25),BPO(25),AMPO(25),BMPO(25),AMP1(25),BMP1(25),AMPS(25),
XBMP5(25),AP(25,25),BP(25,25),LENGTH(25),H(25,2),NPRINT
COMMON/4/POU,POL,PU(25),PL(25),MU(25),ML(25),B(77)
COMMON/5/C(77,77)
COMMON/6/AD(25),BD(25),AE(25),BE(25),AF(25),BF(25),AG(25),BG(25)
COMMON/7/AA(25),BA(25),AB(25),BB(25),AC(25),BC(25)

C      TYPE REAL KA,KB,MATA,MATB,MRPIA,MRPIB,MRPOA,MRPCB,
XMTHPA,MTHPIB,MTHPOA,MTHPOB,MU,ML

C      DIMENSION SUM7(25),SUM8(25)

C      SUM1=SUM2=SUM3=SUM4=SUM5=SUM6=0.
DO 100 I=1,M1
  SUM1=SUM1+MATA(M1,I)*APO(I)
  SUM2=SUM2+MATA(M1,I)*AMPS(I)
  SUM3=SUM3+R(I)*(QPOA(I)-QPIA(I+1))
  SUM4=SUM4+MATB(M1,I)*BPO(I)
  SUM5=SUM5+MATB(M1,I)*BMPS(I)
  SUM6=SUM6+R(I)*(QPOB(I)-QPIB(I+1))
100 CONTINUE
  SUM3=SUM3/R(M)
  SUM6=SUM6/R(M)
  DO 105 J=1,M1
    SUM7(J)=SUM8(J)=0.
    DO 105 I=J,M1
      SUM7(J)=SUM7(J)+MATA(M1,I)*AP(I,J)
      SUM8(J)=SUM8(J)+MATB(M1,I)*BP(I,J)
105 CONTINUE
    MT1=MT-1
    C(MT1,1)=KA*(AA(M1)*SUM1+AG(M)/(2.*PI*R(M)))
    C(MT,1)=-KB*(BA(M1)*SUM4+BG(M)/(2.*PI*R(M)))
    CC1=CC2=0
    DO 110 J=1,M1
      C(MT1,J+1)=KA*(AA(M1)*SUM7(J)+AG(M)*R(J)/R(M))
      C(MT,J+1)=-KB*(BA(M1)*SUM8(J)+BG(M)*R(J)/R(M))
      CC1=CC1+C(MT1,J+1)*PU(J)
      CC2=CC2+C(MT,J+1)*PL(J)
110 CONTINUE
    CC3=CC4=0
    DO 115 I=1,M2
      C(MT1,M+I)=KA*AA(M1)*(MATA(M1,I+1)*AMPO(I+1)+MATA(M1,I)*AMP1(I))
      C(MT,MD+I)=KB*BA(M1)*(MATB(M1,I+1)*BMPO(I+1)+MATB(M1,I)*BMP1(I))
      CC3=CC3+C(MT1,M+I)*MU(I)
      CC4=CC4+C(MT,MD+I)*ML(I)
115 CONTINUE
    C(MT1,MD-1)=KA*AA(M1)*(1.+MATA(M1,M1)*AMP1(M1))
    C(MT1,MD)=KA*AA(M1)*MATA(M1,M1)*(-AA(M)*AC(M1))-AE(M)
    C(MT,MT1)=KB*BA(M1)*(1.+MATB(M1,M1)*BMP1(M1))
    C(MT,MT)=KB*BA(M1)*MATB(M1,M1)*(-BA(M)*BC(M1))-BE(M)
    B(MT1)=KA*(AA(M1)*MRPIA(M)-AE(M)*MRPOA(M)-AC(M)/R(M)*THPOA(M)
X-AA(M1)*SUM2+AG(M)*SUM3)+C(MT1,1)*POU+CC1-CC3-C(MT1,MD-1)*MU(M-1)
    B(MT)=KB*(BA(M1)*MRPIB(M)-BE(M)*MRPOB(M)-BC(M)/R(M)*THPOB(M)
X-BA(M1)*SUM5+BG(M)*SUM6)+C(MT,1)*POL+CC2-CC4-C(MT,MT1)*ML(M-1)
    RETURN
  ENC

```

5. Computer Program for Subroutine EDGE 2

```

SUBROUTINE EDGE2
C
C  * IN THIS SUBROUTINE THE SOLUTION VECTOR IS NAMED BB
C
COMMON/1/M,M1,M2,MD,MT,NRR,PI,THA,THB,KAPA,KAPB,R(25),RR(100),
XNSHELL,MATA(25,25),MATB(25,25),WPIA(25),WPIB(25),WPOA(25),
XWPCB(25),QPIA(25),QPIB(25),QPOA(25),QPOB(25),MRPIA(25),MRPIB(25),
XMRPOA(25),MRPOB(25),THPIA(25),THPIB(25),THPOA(25),THPOB(25),
XAPO(25),BPO(25),AMPO(25),BMPO(25),AMP1(25),BMP1(25),AMPS(25),
XBMP5(25),AP(25,25),BP(25,25),LENGTH(25),H(25,2),NPRINT
COMMON/4/POU,POL,PU(25),PL(25),MU(25),ML(25),BB(77)
COMMON/5/C(77,77)
COMMON/6/AD(25),BD(25),AE(25),BE(25),AF(25),BF(25),AG(25),BG(25)
COMMON/7/AA(25),BA(25),AB(25),XX(25),AC(25),BC(25)
COMMON/12/GGE(5,3),XXE(5,3),YYE(5,3),E(3),NU(3),T(3),ALF(3),
XB(3),D(3),SIN,COS,SINH,COSH,RU(3),PS(3),PM(3),PUL,MALA,MALB,MALP
C
C  TYPE REAL NU,LENGTH,MU,ML,MATA,MATB,MRPIA,MRPIB,MRPOA,MRPOB,L,
XMAIA,MALB,MALP,MBUA,MBUB,MBUP,MAIIA,MALP,MALB,MALP
C
C  DIMENSION AZB(25),BZB(25),AZE(25),BZE(25),S21(25),S22(25),S51(25),
XS52(25),PQ(3),SUM3A(25),SUM3B(25),AZH(25),BZH(25),AZK(25),BZK(25)
C
2 FORMAT (6E12.0)
7 FORMAT (*0*6E20.4)
8000 FORMAT(/24X,*QUANTITIES PERTAINING TO EDGE2*/24X,*-----
X-----*/)
8005 FORMAT(9X,*MAUA*,10X,*MBLB*,10X,*MALA*,10X,*MBLB*,10X,*MALB*/
XE16.4,4E14.4//9X,*MAUP*,10X,*MBLP*,10X,*MALP*,10X,*MBUP*,10X,*MBUA
X*/E16.4,4E14.4//9X,*QAUA*,10X,*QBLB*,10X,*QALA*,10X,*QBUB*,10X,*QA
XLB*/E16.4,4E14.4//9X,*QAUP*,10X,*QBLP*,10X,*QALP*,10X,*QBUP*,10X,*
XQBUA*/E16.4,4E14.4//)
8500 FORMAT(/16X,*AZA*,11X,*AZC*,11X,*AZD*,11X,*AZF*/E23.4,3E14.4)
8505 FORMAT(/16X,*BZA*,11X,*BZC*,11X,*BZD*,11X,*BZF*/E23.4,3E14.4)
8510 FORMAT(/17X,*AT*,11X,*AUL*,11X,*AULA*,10X,*AULB*/E23.4,3E14.4)
8515 FORMAT(/17X,*BT*,11X,*BUL*,11X,*BULA*,10X,*BULB*/E23.4,3E14.4)
8520 FORMAT(/9X,*REGION*,7X,*AZB*,11X,*BZB*,11X,*AZH*,11X,*BZH*)
8525 FORMAT(/9X,*REGION*,7X,*AZE*,11X,*BZE*,11X,*AZK*,11X,*BZK*)
8530 FORMAT(I13,E16.4,3E14.4)
C
C  E= MODULUS OF ELASTICITY FOR PORTION OF OUTERMOST CYLINDER
C  NU=POISSONS RATIO FOR PORTION OF OUTERMOST CYLINDER
C  T=THICKNESS OF PORTION OF OUTERMOST CYLINDER
C  H=THICKNESS OF PLATE AT EDGE
C
IF(EOF,60)999,2000
C
2000 CONTINUE
C
READ2,(E(I),NU(I),T(I),ALF(I),I=1,3)
DO 100 I=1,3
READ 2,(GGE(LL,I),LL=1,4)
READ 2,(XXE(LL,I),LL=1,4)
READ 2,(YYE(LL,I),LL=1,4)
100 CONTINUE
C
HA=H(M,1)
HB=H(M,2)
L=LENGTH(M)
DO 105 I=1,3
IF (T(I).EQ.0.) 60,65

```

```

60 T(I)=0.00000001
65 CONTINUE
  B(I)=SQRTF(SQRTF(3.*(1.-NU(I))/(R(M)**2*T(I)**2)))
  D(I)=E(I)*T(I)**3/(12.*(1.-NU(I)**2))
  CZ1=0.25/B(I)**4
  CZ2=E(I)*ALF(I)*T(I)/R(M)
  CZ3=R(M)/12.*T(I)/(1.-NU(I))
  RU(I)=CZ1*(GGE(1,I)+CZ2*(XXE(1,I)-2.*CZ3*YYE(3,I)))/D(I)
  PS(I)=CZ1*(GGE(2,I)+CZ2*(XXE(2,I)-6.*CZ3*YYE(4,I)))/D(I)
  PM(I)=-CZ1*(2.*GGE(3,I)+2.*CZ2*XXE(3,I))
  PQ(I)=-CZ1*(6.*GGE(4,I)+6.*CZ2*XXE(4,I))
105 CONTINUE
  PUU=RU(2)
  PMU=PM(2)
  PSU=PS(2)
  PQU=PQ(2)
  AT=E(1)*HA**3*THA/(12.*R(M)*(R(M)-THA/2.))
  BT=E(3)*HB**3*THB/(12.*R(M)*(R(M)-THB/2.))
  Z=L
  GU=GS=GM=GQ=0.
  DO200 I=1,4
    GI=I-1
    GZ=GGE(I,2)*Z**(I-1)
    GU=GU+GZ
    GS=GS+GZ*GI/Z
    GM=GM+GZ*GI*(GI-1.)/Z**2
    GQ=GQ+GZ*GI*(GI-1.)*(GI-2.)/Z**3
200 CONTINUE
  XU=XS=XM=XQ=0.
  DO205 I=1,4
    XI=I-1
    XZ=XXE(I,2)*Z**(I-1)
    XU=XU+XZ
    XS=XS+XZ*XI/Z
    XM=XM+XZ*XI*(XI-1.)/Z**2
    XQ=XQ+XZ*XI*(XI-1.)*(XI-2.)/Z**3
205 CONTINUE
  YC=4.*B(2)**4*Z**4
  YU=YS=YM=YT=YQ=0.
  DO210 J=1,4
    YJ=J-1
    YZ=YYE(J,2)*Z**(J-1)
    YU=YU+YZ*YJ*(YJ-1.)*Z**2
    YS=YS+YZ*YJ*(YJ-1.)*(YJ-2.)*Z
    YM=YM+YZ*(YJ*(YJ-1.)*(YJ-2.)*(YJ-3.))-YC
    YT=YT+YZ*(YJ*(YJ-1.)*(YJ-2.)*(YJ-3.))-YC/NU(2)
    YQ=YQ+YZ*YJ*((YJ-1.)*(YJ-2.)*(YJ-3.)*(YJ-4.))-YC/Z
210 CONTINUE
  YA=E(2)*ALF(2)*T(2)/R(M)
  YB=R(M)*T(2)/(12.*(1.-NU(2)))
  YD=.25/B(2)**4
  PUL=YD/D(2)*(GU+YA*(XU-YB*YU))
  PSL=YD/D(2)*(GS+YA*(XS-YB*YS))
  PML=-YD*(GM+YA*(XM-YB*YM))
  PTL=-YD*NU(2)*(GM+YA*(XM-YB*YT))
  PQL=-YD*(GQ+YA*(XQ-YB*YQ))
  PNL=R(M)*(GU-YA*YB*YU)
  ARG=B(2)*Z
  Y=EXPF(ARG)
  COSH=(Y+1./Y)/2.
  IF(ABSF(ARG).LT.0.1)90,85

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```

85 SINH=(Y-1./Y)/2.
GO TO 95
90 AG2=ARG**2
SINH=ARG*(1.+AG2*(1.+AG2*(1.+AG2*(1.+AG2/72.)/42.)/20.)/6.)
95 CONTINUE
SIN=SINF(B(2)*Z)
COS=COSF(B(2)*Z)
T1=(SIN*COS-SINH*COSH)/B(2)
T2=(SIN*COSH-COS*SINH)/B(2)
T3=SIN**2+SINH**2
T4=SIN*SINH
T5=SIN**2-SINH**2
T6=SIN**2*COSH**2-COS**2*SINH**2
T7=T4*T3+COS*COSH*T5
F1=2.*D(2)*B(2)**2/T5
F2=F1/T2
F3=2.*D(1)*B(1)**2
F4=2.*D(3)*B(3)**2
MALA=F1*(T1-HA*T3/2.)
MALB=-F1*(T2+HB*T4)
MALP=F1*(T3*PUU-2.*T4*PUL-T1*PSU+T2*PSL)+PMU
MBUA=F1*(T2+HA*T4)
MBUB=-F1*(T1-HB*T3/2.)
MBUP=-F1*(2.*T4*PUU-T3*PUL+T2*PSU-T1*PSL)+PML
QALA=F2*(T2*T3+HA*T7)
QALB=F2*(2.*T2*T4+HB*T6)
QALP=-F2*(2.*T7*PUU-2.*T6*PUL+T2*T3*PSU+2.*T2*T4*PSL)+PQU
QBUA=F2*(2.*T2*T4+HA*T6)
QBUB=F2*(T2*T3+HB*T7)
QBUP=-F2*(2.*T6*PUU-2.*T7*PUL+2.*T2*T4*PSU+T2*T3*PSL)+PQL
MAUA=-F3*(HA/2.+1./B(1))
MAUP=-F3*(RU(1)+PS(1)/B(1))+PM(1)
QAUA=F3*(HA*B(1)+1.)
QAUP=F3*(2.*B(1)*RU(1)+PS(1))+PQ(1)
MBLB=F4*(HB/2.+1./B(3))
MBLP=-F4*(RU(3)+PS(3)/B(3))+PM(3)
QBLB=-F4*(HB*B(3)+1.)
QBLP=F4*(2.*B(3)*RU(3)+PS(3))+PQ(3)
AUL=MAUP-MALP+HA*(QALP-QAUP)/2.
AULA=R(M)*(MAUA-MALA+HA*(QALA-QAUA)/2.-AT)/AC(M)
BULA=R(M)*(-MALB+HA*QALB/2.)/BC(M)
BUL=MBUP-MBLP+HB*(QBLP-QBUP)/2.
AULB=R(M)*(MBUA+HB*QBUA/2.)/AC(M)
BULB=R(M)*(MBUB-MBLB+HB*(QBLB-QBUB)/2.-BT)/BC(M)
SUM2A=SUM4A=SUM5A=SUM2B=SUM4B=SUM5B=0.
DO 115 I=1,M1
SUM2A=SUM2A+MATA(M1,I)*APO(I)
SUM2B=SUM2B+MATB(M1,I)*BPO(I)
SUM4A=SUM4A+MATA(M1,I)*AMPS(I)
SUM4B=SUM4B+MATB(M1,I)*BMPS(I)
SUM5A=SUM5A+R(I)*(QPOA(I)-QPIA(I+1))
SUM5B=SUM5B+R(I)*(QPOB(I)-QPIB(I+1))
SUM3A(I)=SUM3B(I)=0.
DO 115 J=1,M1
SUM3A(I)=SUM3A(I)+MATA(M1,J)*AP(J,I)
SUM3B(I)=SUM3B(I)+MATB(M1,J)*BP(J,I)
115 CONTINUE
SUM5A=SUM5A/R(M)
SUM5B=SUM5B/R(M)
S11=AA(M)*AC(M1)*AA(M1)*MATA(M1,M1)+AE(M)
S12=BA(M)*BC(M1)*BA(M1)*MATB(M1,M1)+BE(M)

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DO 120 I=1,M2
S21(I)=AA(M1)*(MATA(M1,I+1)*AMPO(I+1)+MATA(M1,I)*AMP1(I))
S22(I)=BA(M1)*(MATB(M1,I+1)*BMPO(I+1)+MATB(M1,I)*BMP1(I))
120 CONTINUE
S31=AA(M1)*(MATA(M1,M1)*AMP1(M1)+1.)
S32=BA(M1)*(MATB(M1,M1)*BMP1(M1)+1.)
S41=AA(M1)*SUM2A+AG(M)/(2.*PI*R(M))
S42=BA(M1)*SUM2B+BG(M)/(2.*PI*R(M))
DO 125 I=1,M1
S51(I)=AA(M1)*SUM3A(I)+R(I)*AG(M)/R(M)
S52(I)=BA(M1)*SUM3B(I)+R(I)*BG(M)/R(M)
125 CONTINUE
S61=AA(M1)*SUM4A-AA(M1)*MRPIA(M)+AE(M)*MRPOA(M)-AG(M)*SUM5A
X+THPOA(M)*AC(M)/R(M)
S62=BA(M1)*SUM4B-BA(M1)*MRPIB(M)+BE(M)*MRPOB(M)-BG(M)*SUM5B
X+THPOB(M)*BC(M)/R(M)
AZA=-AULA*S11
BZA=-BULA*S12
AZG=-AULB*S11
BZG=-BULB*S12
DO 130 I=1,M2
AZB(I)=AULA*S21(I)
BZB(I)=BULA*S22(I)
AZH(I)=AULB*S21(I)
BZH(I)=BULB*S22(I)
130 CONTINUE
AZC=AULA*S31
BZC=BULA*S32
AZI=AULB*S31
BZI=BULB*S32
AZD=AULA*S41
BZD=BULA*S42
AZJ=AULB*S41
BZJ=BULB*S42
DO 135 I=1,M1
AZE(I)=AULA*S51(I)
BZE(I)=BULA*S52(I)
AZK(I)=AULB*S51(I)
BZK(I)=BULB*S52(I)
135 CONTINUE
AZF=AULA*S61
BZF=BULA*S62
AZL=AULB*S61
BZL=BULB*S62

C
IF(NPRINT.EQ.0) GO TO 155
PRINT 8000
PRINT 8005, MAUA,MBLB,MALA,MBUB,MALB,MAUP,MBLP,MALP,MBUP,
XMBUA,QAUA,QBLB,QALA,QBUB,QALB,QAUP,QBLP,QALP,QBUP,QBUA
PRINT 8500, AZA,AZC,AZD,AZF
PRINT 8505, BZA,BZC,BZD,BZF
PRINT 8510, AT,AUL,AULA,AULB
PRINT 8515, BT,BUL,BULA,BULB
PRINT 8520
PRINT 8530, (N,AZB(N),BZB(N),AZH(N),BZH(N),N=1,M2)
PRINT 8525
PRINT 8530, (N,AZE(N),BZE(N),AZK(N),BZK(N),N=1,M1)
155 CONTINUE

C
SUM1=SUM2=SUM3=SUM4=SUM5=SUM6=SUM7=SUM8=0.
DO 140 I=1,M2

```

```

SUM1=SUM1+AZE(I)*PU(I)
SUM2=SUM2+BZE(I)*PL(I)
SUM3=SUM3+AZB(I)*MU(I)
SUM4=SUM4+BZB(I)*ML(I)
SUM5=SUM5+AZK(I)*PU(I)
SUM6=SUM6+BZK(I)*PL(I)
SUM7=SUM7+AZH(I)*MU(I)
SUM8=SUM8+BZH(I)*ML(I)
140 CONTINUE
SUM1=SUM1+AZE(M1)*PU(M1)
SUM2=SUM2+BZE(M1)*PL(M1)
SUM5=SUM5+AZK(M1)*PU(M1)
SUM6=SUM6+BZK(M1)*PL(M1)
BB(MT-1)=AZD*POU-BZD*POL+SUM1-SUM2-SUM3-SUM4-AZC*MU(M1)
X-BZC*ML(M1)-AZF-BZF-AUL
BB(MT)=AZJ*POU-BZJ*POL+SUM5-SUM6-SUM7-SUM8-AZI*MU(M1)
X-BZI*ML(M1)-AZL-BZL-BUL
C(MT-1,1)=AZD-BZD
C(MT-1,MD-1)=AZC
C(MT-1,MD)=AZA-1.
C(MT-1,MT-1)=BZC
C(MT-1,MT)=BZA
C(M1,1)=AZJ-BZJ
C(MT,MD-1)=AZI
C(MT,MD)=AZG
C(MT,MT-1)=BZI
C(MT,MT)=BZG-1.
DO 145 I=1,M1
C(MT-1,I+1)=AZE(I)-BZE(I)
C(MT,I+1)=AZK(I)-BZK(I)
145 CONTINUE
DO 150 I=1,M2
C(MT-1,M+I)=AZB(I)
C(MT-1,MD+I)=BZB(I)
C(MT,M+I)=AZH(I)
C(MT,MD+I)=BZH(I)
150 CONTINUE
999 CONTINUE
END

```

6. Computer Program for Subroutine SHELLOUT

```

C      COMMON/10/XG(5),XA(5),XB(5),SE,SV,ST,SALF,SA,SC1,SC2,SC3,SC4
C
800  FORMAT (F9.3,5E13.4)
C
      IF(Z.EQ.0) Z=0.00001
C
      SB=SQRTF(SQRTF(3.*(1.-SV)/(SA**2*ST**2)))
      SD=SE*ST**3/(12.*(1.-SV**2))
C
      GU=GS=GM=GQ=0.
      DO200 I=1,4
      GI=I-1
      GZ=XG(I)*Z**(I-1)
      GU=GU+GZ
      GS=GS+GZ*GI/Z
      GM=GM+GZ*GI*(GI-1.)/Z**2
      GQ=GQ+GZ*GI*(GI-1.)*(GI-2.)/Z**3
200  CONTINUE
      XU=XS=XM=XQ=0.
      DO205 I=1,4
      XI=I-1
      XZ=XA(I)*Z**(I-1)
      XU=XU+XZ
      XS=XS+XZ*XI/Z
      XM=XM+XZ*XI*(XI-1.)/Z**2
      XQ=XQ+XZ*XI*(XI-1.)*(XI-2.)/Z**3
205  CONTINUE
C
      YC=4.*SB**4*Z**4
      YU=YS=YM=YT=YQ=0.
      DO210 J=1,4
      YJ=J-1
      YZ=XB(J)*Z**(J-1)
      YU=YU+YZ*YJ*(YJ-1.)*Z**2
      YS=YS+YZ*YJ*(YJ-1.)*(YJ-2.)*Z
      YM=YM+YZ*(YJ*(YJ-1.)*(YJ-2.)*(YJ-3.))-YC)
      YT=YT+YZ*(YJ*(YJ-1.)*(YJ-2.)*(YJ-3.))-YC/SV)
      YQ=YQ+YZ*YJ*((YJ-1.)*(YJ-2.)*(YJ-3.)*(YJ-4.))-YC)/Z
210  CONTINUE
      YA=SE*SALF*ST/SA
      YB=SA*ST/(12.*(1.-SV))
      YD=.25/SB**4
      SU=YD/SD*(GU+YA*(XU-YB*YU))
      SS=YD/SD*(GS+YA*(XS-YB*YS))
      SM=-YD*(GM+YA*(XM-YB*YM))
      SX=-YD*SV*(GM+YA*(XM-YB*YT))
      SQ=-YD*(GQ+YA*(XQ-YB*YQ))
      SN=SA*(GU-YA*YB*YU)
      ARG=SB*Z
      Y=EXP(ARG)
      COSH=(Y+1./Y)/2.
      IF(ABS(ARG).LT.0.1) 90,85
85  SINH=(Y-1./Y)/2.
      GO TO 95
90  AG2=ARG**2
      SINH=ARG*(1.+AG2*(1.+AG2*(1.+AG2*(1.+AG2/72.)/42.)/20.)/6.)
95  CONTINUE
      SIN=SINF(SB*Z)
      COS=COSF(SB*Z)

```

```
COEF=2.*SB**2*SD
ZX=SC1*SIN*SINH+SC2*SIN*COSH+SC3*COS*SINH+SC4*COS*COSH
ZY=SC1*COS*COSH+SC2*COS*SINH-SC3*SIN*COSH-SC4*SIN*SINH
ZU=ZX+SU
ZM=-COEF*ZY+SM
ZT=-COEF*SV*ZY+SX
ZQ=-COEF*SB*(SC1*(COS*SINH-SIN*COSH)+SC2*(COS*COSH-SIN*SINH)
X-SC3*(COS*COSH+SIN*SINH)-SC4*(COS*SINH+SIN*COSH))+SQ
ZN=SE*ST/SA*ZX+SN
IF(Z.EQ.0.00001) Z=0.
```

C

```
PRINT 800, Z,ZU,ZN,ZM,ZT,ZQ
```

C

```
RETURN
END
```


7. Computer Program for Subroutine MATINV

```

C
C   MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
C
C   DIMENSION A(NMAX,NSUB), B(NMAX,MSUB)
C   COMMON /402/ PIVOT(100), INDEX(100), IPIVOT(100)
C   EQUIVALENCE (PIVOT,INDEX,IPIVOT), (AMAX,T), (IROW,I1,IRC),
C   X(TEMP,SWAP)
C   DATA (ISHIFT=4096), (MASK=0000000077777777B)
C
C   N=NSUB
C   M=MSUB
C
C   C   INITIALIZATION
C
C   DETERM=1.0
C   DO 20 I=1,N
C   IPIVOT(I)=0
20  CONTINUE
C   DO 550 I=1,N
C
C   C   SEARCH FOR PIVOT ELEMENT
C
C   AMAX=0.0
C   DO 105 J=1,N
C   TEMP=IPIVOT(J).AND..NOT.MASK
C   IF (TEMP) 105, 60
60  DO 100 K=1,N
C   TEMP=IPIVOT(K).AND..NOT.MASK
C   IF (TEMP) 100, 80
80  TEMP=ABSF(A(J,K))
C   IF (TEMP-AMAX) 100, 85, 85
85  IROW=J
C   ICOLUM=K
C   AMAX=TEMP
100 CONTINUE
105 CONTINUE
C   INDEX(I)=INDEX(I) + (ISHIFT*IROW+ICOLUM)
C   J=IROW
C   AMAX=A(J,ICOLUM)
C   DETERM=AMAX*DETERM
C
C   C   RETURN IF MATRIX IS SINGULAR
C
C   110 PIVOT(ICOLUM)=INDEX(ICOLUM).OR.AMAX.AND..NOT.MASK
C
C   C   INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
C   IF (IROW-ICOLUM) 140, 260
140 DETERM=-DETERM
C   DO 200 K=1,N
C   SWAP=A(J,K)
C   A(J,K)=A(ICOLUM,K)
C   A(ICOLUM,K)=SWAP
200 CONTINUE
C   DO 250 K=1,M
C   SWAP=B(J,K)
C   B(J,K)=B(ICOLUM,K)
C   B(ICOLUM,K)=SWAP
250 CONTINUE

```

```

C
C      DIVIDE PIVOT ROW BY PIVOT ELEMENT
C

```

```

260 K=ICOLUM
   A(ICOLUM,K)=1.0
   DO 350 K=1,N
     A(ICOLUM,K)=A(ICOLUM,K)/AMAX
350 CONTINUE
   DO 370 K=1,M
     B(ICOLUM,K)=B(ICOLUM,K)/AMAX
370 CONTINUE

```

```

C
C      REDUCE NON-PIVOT ROWS
C

```

```

   DO 550 J=1,N
     IF( J-ICOLUM) 400, 550
400 T=A( J,ICOLUM)
     A( J,ICOLUM)=0.0
     DO 450 K=1,N
       A( J,K)=A( J,K)-A(ICOLUM,K)*T
450 CONTINUE
     DO 500 K=1,M
       B( J,K)=B( J,K)-B(ICOLUM,K)*T
500 CONTINUE
550 CONTINUE

```

```

C
C      INTERCHANGE COLUMNS
C

```

```

600 DO 710 I=1,N
     I1=N+1-I
     IRC=INDEX(I1).AND.MASK
     K=IRC/ISHIFT
     ICOLUM=IRC-K*ISHIFT
     IF (K-ICOLUM) 650, 710
650 DO 705 J=1,N
     SWAP=A(J,K)
     A(J,K)=A(J,ICOLUM)
     A(J,ICOLUM)=SWAP
705 CONTINUE
710 CONTINUE

```

```

C
C      740 DET=DETERM
C      RETURN

```

```

C
C      ENTRY QMATINV
C      RETURN

```

```

C
C      END

```

APPENDIX D

Sample Output

CONTROL VARIABLES

SYMBOL	VALUE	COMMENTS
M	= 5	TOTAL NUMBER OF REGIONS PER PLATE
NEDGE	= 1	1 FOR EDGE1, =2 FOR EDGE2 CONDITIONS
NSHELL	= 0	0 FOR NO INTERMEDIATE SHELLS, OTHERWISE -0
NRR	= 15	NUMBER OF PLATE RADII AT WHICH RESULTS ARE TO BE PRINTED
NPRINT	= 0	0 FOR ONLY INPUT AND FINAL RESULTS TO BE PRINTED, -0 FOR ADDITIONAL MATERIAL
NRIGID	= 0	1 FOR DEVIATION FROM PERPENDICULARITY OF THE TUBE-PLATE JUNCTION DUE TO SHEAR IN THE TUBES, =2 FOR DEVIATION DUE TO SHEAR IN THE TUBES AND LOCAL DEFORMATION OF THE PLATE, =0 FOR NO DEVIATION FROM PERPENDICULARITY

ADDITIONAL QUANTITIES

KA	KB	KAPA	KAPB
-0.000	-0.000	-0.000	-0.000

PLATE RADII AT WHICH INFORMATION IS DESIRED

SEQ.NO. K	RADIUS R(K)	SEQ.NO. K	RADIUS R(K)	SEQ.NO. K	RADIUS R(K)	SEQ.NO. K	RADIUS R(K)
1	0.000	2	1.000	3	2.000	4	3.000
5	4.000	6	5.000	7	6.000	8	7.000
9	7.464	10	8.000	11	9.000	12	10.000
13	10.500	14	10.500	15	10.500		

DATA PERTAINING TO TUBES

NO.OF TUBES LAMB.	LOC.OF TUBES R	DIAMETERS		TUBE LENGTH L	MODULUS OF ELAST. E	CROSS SECT. AREA A	MOMENT OF INERTIA I
		INSIDE DI	OUTSIDE DO				
1	0.000	-0.000	0.260	0.374	4.4000+005	5.3093-002	2.2432-004
6	4.000	-0.000	0.260	0.374	4.4000+005	5.3093-002	2.2432-004
12	7.464	-0.000	0.260	0.374	4.4000+005	5.3093-002	2.2432-004
6	10.500	-0.000	0.260	0.374	4.4000+005	5.3093-002	2.2432-004
1	10.500	-0.000	0.000	0.374	4.4000+005	7.8540-015	4.9087-030

EXTERNAL CONCENTRATED LOADING

LOAD LOCATION R	UPPER LOAD PU	UPPER MOMENT MU	LOWER LOAD PL	LOWER MOMENT ML
0.000	-0.0000+000	0.0000+000	-0.0000+000	0.0000+000
4.000	-0.0000+000	-0.0000+000	-0.0000+000	-0.0000+000
7.464	-0.0000+000	-0.0000+000	-0.0000+000	-0.0000+000
10.500	-0.0000+000	-0.0000+000	-0.0000+000	-0.0000+000
10.500	-0.0000+000	-0.0000+000	3.4636+001	-0.0000+000

PROPERTIES OF THE TOP PLATE REGIONS

=====

PHYSICAL CONSTANTS

REGION	OUTSIDE RADIUS R	PLATE THICKNESS H	MODULUS OF ELASTICITY E	POISSONS RATIO NU	EXPANSION COEFFICIENT ALPHA	FLEXURAL RIGIDITY D
1	4.000	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
2	7.464	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
3	10.500	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
4	10.500	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
5	10.500	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002

LOADING PARAMETERS

REGION	TERMS OF THE SERIES				
	1	2	3	4	
1	F	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	A	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	B	-0.000+000	-0.000+000	-0.000+000	-0.000+000
2	F	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	A	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	B	-0.000+000	-0.000+000	-0.000+000	-0.000+000
3	F	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	A	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	B	-0.000+000	-0.000+000	-0.000+000	-0.000+000
4	F	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	A	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	B	-0.000+000	-0.000+000	-0.000+000	-0.000+000
5	F	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	A	-0.000+000	-0.000+000	-0.000+000	-0.000+000
	B	-0.000+000	-0.000+000	-0.000+000	-0.000+000

PROPERTIES OF THE BOTTOM PLATE REGIONS

=====

PHYSICAL CONSTANTS

REGION	OUTSIDE RADIUS R	PLATE THICKNESS H	MODULUS OF ELASTICITY E	POISSONS RATIO NU	EXPANSION COEFFICIENT ALPHA	FLEXURAL RIGIDITY D
1	4.000	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
2	7.464	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
3	10.500	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
4	10.500	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002
5	10.500	0.171	4.4000+005	3.5000-001	1.0000+000	2.0894+002

LOADING PARAMETERS

REGION	TERMS OF THE SERIES			
	1	2	3	4
1	F 1.000-001	-0.000+000	-0.000+000	-0.000+000
	A -0.000+000	-0.000+000	-0.000+000	-0.000+000
	B -0.000+000	-0.000+000	-0.000+000	-0.000+000
2	F 1.000-001	-0.000+000	-0.000+000	-0.000+000
	A -0.000+000	-0.000+000	-0.000+000	-0.000+000
	B -0.000+000	-0.000+000	-0.000+000	-0.000+000
3	F 1.000-001	-0.000+000	-0.000+000	-0.000+000
	A -0.000+000	-0.000+000	-0.000+000	-0.000+000
	B -0.000+000	-0.000+000	-0.000+000	-0.000+000
4	F 1.000-001	-0.000+000	-0.000+000	-0.000+000
	A -0.000+000	-0.000+000	-0.000+000	-0.000+000
	B -0.000+000	-0.000+000	-0.000+000	-0.000+000
5	F -0.000+000	-0.000+000	-0.000+000	-0.000+000
	A -0.000+000	-0.000+000	-0.000+000	-0.000+000
	B -0.000+000	-0.000+000	-0.000+000	-0.000+000

INTERNAL LOADS AT INTERSECTION OF PLATES AND TUBES

LOCATION	AXIAL LOAD	TOP MOMENT	BOTTOM MOMENT
R	P	MU	ML
0.000	-6.1917-001	0.0000+000	0.0000+000
4.000	-1.7471-001	3.4122-001	3.3935-001
7.464	-1.8019-001	5.9700-001	5.9071-001
10.500	-3.4009-006	3.0586-001	3.1945-001
10.500	-4.5389-020	1.1246-027	1.1800-027
10.500	0.0000+000	0.0000+000	0.0000+000

RESULTANT INFORMATION ON PLATES IN BENDING

=====

TOP PLATE

FINAL RESULTS

REGULAR BENDING SOLUTION				RIGID SPACER SOLUTION		
RADIAL DIST. R	PLATE DEFL. W	RADIAL STRESS SRB	TANGENTIAL STRESS STB	PLATE DEFL. WR	RADIAL STRESS SRR	TANG. STRESS STR
0.000	1.1113-002	2.6647+002	2.7304+002	5.723-003	7.525+000	7.525+000
1.000	1.0836-002	1.5052+001	2.1624+001	5.658-003	7.456+000	7.483+000
2.000	1.0334-002	5.5917+000	1.2163+001	5.465-003	7.252+000	7.358+000
3.000	9.7914-003	5.7595-002	6.6292+000	5.147-003	6.910+000	7.149+000
4.000	9.3066-003	-3.8689+000	2.7027+000	4.713-003	6.433+000	6.856+000
4.000	9.3066-003	6.6147+001	2.7208+001	4.713-003	6.433+000	6.856+000
5.000	8.3138-003	2.4923+001	1.9145+001	4.172-003	5.818+000	6.481+000
6.000	6.8085-003	-4.2193+000	8.0160+000	3.537-003	5.068+000	6.021+000
7.000	5.4751-003	-2.6674+001	-3.5776+000	2.823-003	4.180+000	5.478+000
7.464	5.0575-003	-3.5576+001	-8.8552+000	2.470-003	3.722+000	5.198+000
7.464	5.0575-003	8.6924+001	3.4020+001	2.470-003	3.722+000	5.198+000
8.000	4.4290-003	5.3675+001	2.6121+001	2.049-003	3.157+000	4.852+000
9.000	2.4976-003	8.4191-001	9.0554+000	1.237-003	1.996+000	4.142+000
10.000	6.0774-004	-4.3213+001	-9.4156+000	4.103-004	6.996-001	3.348+000
10.500	1.7353-009	-6.2761+001	-1.8823+001	1.631-009	1.398-006	2.920+000
10.500	1.7379-009	8.3145-005	3.1234+000	1.631-009	8.693-004	2.919+000
10.500	8.6584-010	4.1577-005	3.1234+000	8.166-010	8.679-004	2.919+000
10.500	8.6482-010	4.1559-005	3.1233+000	8.166-010	-2.785-007	2.926+000
10.500	0.0000+000	-9.7479-009	3.1233+000	0.000+000	7.616-011	2.926+000

BOTTOM PLATE

FINAL RESULTS

REGULAR BENDING SOLUTION				RIGID SPACER SOLUTION		
RADIAL DIST. R	PLATE DEFL. W	RADIAL STRESS SRB	TANGENTIAL STRESS STB	PLATE DEFL. WR	RADIAL STRESS SRR	TANG. STRESS STR
0.000	1.1122-002	-1.3222+002	-1.3879+002	5.723-003	7.525+000	7.525+000
1.000	1.1061-002	2.0620+001	1.5716+001	5.658-003	7.456+000	7.483+000
2.000	1.0639-002	1.7192+001	1.7289+001	5.465-003	7.252+000	7.358+000
3.000	9.9418-003	1.2453+000	9.6783+000	5.147-003	6.910+000	7.149+000
4.000	9.3183-003	-2.4902+001	-4.7983+000	4.713-003	6.433+000	6.856+000
4.000	9.3183-003	4.4731+001	1.9573+001	4.713-003	6.433+000	6.856+000
5.000	8.4488-003	3.0950+001	2.0314+001	4.172-003	5.818+000	6.481+000
6.000	6.9672-003	3.9591+000	1.1399+001	3.537-003	5.068+000	6.021+000
7.000	5.5061-003	-3.4788+001	-5.8326+000	2.823-003	4.180+000	5.478+000
7.464	5.0688-003	-5.6511+001	-1.6417+001	2.470-003	3.722+000	5.198+000
7.464	5.0688-003	6.4698+001	2.6006+001	2.470-003	3.722+000	5.198+000
8.000	4.5155-003	5.0399+001	2.4061+001	2.049-003	3.157+000	4.852+000
9.000	2.7285-003	1.3345+001	1.3286+001	1.237-003	1.996+000	4.142+000
10.000	7.3139-004	-3.6282+001	-6.1404+000	4.103-004	6.996-001	3.348+000
10.500	2.4247-009	-6.5548+001	-1.8903+001	1.631-009	1.398-006	2.920+000
10.500	2.3610-009	2.6000-002	4.1916+000	1.631-009	8.693-004	2.919+000
10.500	1.1914-009	2.5935-002	4.1916+000	8.166-010	8.679-004	2.919+000
10.500	1.1885-009	-4.2271-005	4.2623+000	8.166-010	-2.785-007	2.926+000
10.500	0.0000+000	-0.0000+000	4.2623+000	0.000+000	7.616-011	2.926+000

RESULTANT APPROXIMATE MEMBRANE SOLUTION

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TOP PLATE

FINAL RESULTS

REGULAR BENDING SOLUTION				RIGID SPACER SOLUTION		
RADIAL DIST. R	PLATE DEFL. U	RADIAL STRESS SRM	TANGENTIAL STRESS STM	PLATE DEFL. UR	RADIAL STRESS SMR	TANG. STRESS SMT
0.000	-3.3503-010	-2.2679+001	-2.2679+001	-3.543-010	-2.398+001	-2.398+001
1.000	-3.3503-005	-2.2679+001	-2.2679+001	-3.530-005	-2.376+001	-2.385+001
2.000	-6.7006-005	-2.2679+001	-2.2679+001	-6.982-005	-2.311+001	-2.345+001
3.000	-1.0051-004	-2.2679+001	-2.2679+001	-1.028-004	-2.202+001	-2.278+001
4.000	-1.3401-004	-2.2679+001	-2.2679+001	-1.334-004	-2.050+001	-2.185+001
4.000	-1.3401-004	-1.5376+001	-2.0123+001	-1.334-004	-2.050+001	-2.185+001
5.000	-1.5441-004	-1.6231+001	-1.9269+001	-1.610-004	-1.854+001	-2.065+001
6.000	-1.7675-004	-1.6695+001	-1.8805+001	-1.846-004	-1.615+001	-1.919+001
7.000	-2.0019-004	-1.6975+001	-1.8525+001	-2.036-004	-1.332+001	-1.746+001
7.464	-2.1133-004	-1.7068+001	-1.8431+001	-2.106-004	-1.186+001	-1.657+001
7.464	-2.1133-004	-4.3237+000	-1.3971+001	-2.106-004	-1.186+001	-1.657+001
8.000	-2.1117-004	-4.9483+000	-1.3346+001	-2.171-004	-1.006+001	-1.546+001
9.000	-2.1323-004	-5.8295+000	-1.2465+001	-2.245-004	-6.363+000	-1.320+001
10.000	-2.1758-004	-6.4599+000	-1.1835+001	-2.248-004	-2.230+000	-1.067+001
10.500	-2.2041-004	-6.7097+000	-1.1585+001	-2.220-004	-2.771-003	-9.303+000
10.500	-2.2041-004	1.7592-006	-9.2363+000	-2.220-004	-2.771-003	-9.303+000
10.500	-2.2041-004	8.7952-007	-9.2363+000	-2.225-004	8.877-007	-9.325+000
10.500	-2.2041-004	8.7975-007	-9.2363+000	-6.982-005	2.785-007	-2.926+000
10.500	-2.2041-004	1.1642-010	-9.2363+000	-6.982-005	-7.616-011	-2.926+000

BOTTOM PLATE

FINAL RESULTS

REGULAR BENDING SOLUTION				RIGID SPACER SOLUTION		
RADIAL DIST. R	PLATE DEFL. U	RADIAL STRESS SRM	TANGENTIAL STRESS STM	PLATE DEFL. UR	RADIAL STRESS SMR	TANG. STRESS SMT
0.000	3.3503-010	2.2679+001	2.2679+001	3.543-010	2.398+001	2.398+001
1.000	3.3503-005	2.2679+001	2.2679+001	3.530-005	2.376+001	2.385+001
2.000	6.7006-005	2.2679+001	2.2679+001	6.982-005	2.311+001	2.345+001
3.000	1.0051-004	2.2679+001	2.2679+001	1.028-004	2.202+001	2.278+001
4.000	1.3401-004	2.2679+001	2.2679+001	1.334-004	2.050+001	2.185+001
4.000	1.3401-004	1.5376+001	2.0123+001	1.334-004	2.050+001	2.185+001
5.000	1.5441-004	1.6231+001	1.9269+001	1.610-004	1.854+001	2.065+001
6.000	1.7675-004	1.6695+001	1.8805+001	1.846-004	1.615+001	1.919+001
7.000	2.0019-004	1.6975+001	1.8525+001	2.036-004	1.332+001	1.746+001
7.464	2.1133-004	1.7068+001	1.8431+001	2.106-004	1.186+001	1.657+001
7.464	2.1133-004	4.3237+000	1.3971+001	2.106-004	1.186+001	1.657+001
8.000	2.1117-004	4.9483+000	1.3346+001	2.171-004	1.006+001	1.546+001
9.000	2.1323-004	5.8295+000	1.2465+001	2.245-004	6.363+000	1.320+001
10.000	2.1758-004	6.4599+000	1.1835+001	2.248-004	2.230+000	1.067+001
10.500	2.2041-004	6.7097+000	1.1585+001	2.220-004	2.771-003	9.303+000
10.500	2.2041-004	-1.7592-006	9.2363+000	2.220-004	2.771-003	9.303+000
10.500	2.2041-004	-8.7952-007	9.2363+000	6.982-005	-2.785-007	2.926+000
10.500	2.2041-004	-8.7975-007	9.2363+000	6.982-005	-2.785-007	2.926+000
10.500	2.2041-004	-1.1642-010	9.2363+000	6.982-005	7.616-011	2.926+000

RESULTS FOR TUBES SUBJECTED TO MAXIMUM BENDING STRESS

LOCATED AT R= 10.500

DIST. X	DEFLECTION Y	AXIAL STRESS	BENDING STRESS	COMBINED STRESS
0.000	7.4534-005	-7.0432-004	-1.3239+003	-1.3239+003
0.030	9.0846-005	-7.0432-004	-1.1046+003	-1.1046+003
0.060	8.9778-005	-7.0432-004	-8.8526+002	-8.8526+002
0.090	7.4781-005	-7.0432-004	-6.6592+002	-6.6592+002
0.120	4.9307-005	-7.0432-004	-4.4658+002	-4.4658+002
0.150	1.6805-005	-7.0432-004	-2.2723+002	-2.2724+002
0.180	-1.9271-005	-7.0432-004	-7.8931+000	-7.8938+000
0.210	-5.5472-005	-7.0432-004	2.1145+002	-2.1145+002
0.240	-8.8346-005	-7.0432-004	4.3079+002	-4.3079+002
0.270	-1.1444-004	-7.0432-004	6.5013+002	-6.5013+002
0.300	-1.3031-004	-7.0432-004	8.6947+002	-8.6947+002
0.330	-1.3249-004	-7.0432-004	1.0888+003	-1.0888+003
0.360	-1.1755-004	-7.0432-004	1.3082+003	-1.3082+003

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REFERENCES

1. H. Halle, Deformation Analysis of a Circular Coupled-plate Structure, ANL-7145 (March 1966).
2. S. Timoshenko and S. Woinowsky-Krieger, Theory of Plates and Shells, McGraw-Hill Book Co., Inc. (1959), Second Edition.
3. A. H. Marchertas, S. H. Fistedis, and R. O. Brittan, Analytical and Experimental Investigation of a Nuclear Support Structure, ANL-6781 (March 1965).