# AREAS OF CONTACT AND PRESSURE DISTRIBUTION

## IN BOLTED JOINTS

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## ABSTRACT

When two plates are bolted (or riveted) together these will be in contact in the immediate vicinity of the bolt heads and separated beyond it. The pressure distribution and size of the contact zone is of considerable interest in the study of heat transfer across bolted joints.

The pressure distributions in the contact zones and the radii at which flat and smooth axisymmetric, linear elastic plates will separate were computed for several thicknesses as a function of the configuration of the bolt load by the finite element method. The radii of separation were also measured by two experimental methods. One method employed autoradiographic techniques. The other method measured the polished area around the bolt hole of the plates caused by sliding under load in the contact zone. The sliding was produced by rotating one plate of a mated pair relative to the other plate with the bolt force acting.

The computational and experimental results are in agreement and these yield smaller zones of contact than indicated by the literature. It is shown that the discrepancy is due to an assumption made in the previous analyses.

In addition to the above results this report contains the finite element and heat transfer computer programs used in this study. Instructions for the use of these programs are also included. -

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## NOMENCLATURE

| A, B, C  | radii                              |
|--|------------------------------------|
| D  | thickness                          |
| Е  | modulus of elasticity              |
| G  | shear modulus                      |
| h <sub>c</sub> , h <sub>f</sub>                  | heat transfer coefficients         |
| Н  | hardness                           |
| k, k <sub>1</sub> , k <sub>2</sub>               | thermal conductivities             |
| Р, р   | pressure                           |
| r  | coordinate                         |
| Ro   | radius of separation               |
| u,w  | displacement in r and z directions |
| x  | coordinate                         |
| x <sub>c</sub>                                   | length of contact                  |
| У  | coordinate                         |
| у'   | slope                              |
| Z  | coordinate                         |
|  |                                    |
| δ  | deflection                         |
| ε  | dilation                           |
| ε <sub>r</sub> ,ε <sub>t</sub> , ε <sub>rz</sub> | strains                            |
| σ, σ <sub>1</sub> , σ <sub>2</sub>               | standard deviations                |
| σ <sub>r</sub> , σ <sub>t</sub> , σ <sub>z</sub> | stresses                           |

| λ,μ | Lame's constants |
|-----|------------------|
| ν   | Poisson's ratio  |
| τ   | shear stress     |
| θ   | angle            |

Subscripts

| r | radial direction     |  |
|---|----------------------|--|
| t | tangential direction |  |
| Z | z-direction          |  |

### Chapter I

#### INTRODUCTION

When two plates are bolted (or riveted) together, these will be in contact in the immediate vicinity of the bolt heads and separated beyond it. The pressure distribution in the contact area and the separation of the plates is of considerable interest in the study of heat transfer across joints. Cooper, Mikic and Yovanovich [1] show that with assumed Gaussian distribution of surface heights, the microscopic contact conductance is related to the interface pressure, surface characteristics and the hardness of the softer material in

$$h_{c} = 1.45 \frac{\tan \theta}{\sigma} k \left(\frac{P}{H}\right)^{0.985}$$
(1.1)

where

$$k \equiv \frac{2k_1k_2}{k_1 + k_2}$$
(1.2)

and  $k_1$  and  $k_2$  represent the thermal conductivities of two bodies in contact;  $\sigma$  is the combined standard deviation for the two surfaces which can be expressed as

$$\sigma = (\sigma_1^2 + \sigma_2^2)^{1/2}$$
(1.3)

where  $\sigma_1$  and  $\sigma_2$  are the individual standard deviation of height for the respective surfaces; tan  $\theta$  is the mean of the absolute value of slope for the combined profile and it is related, for normal distribution of slope, to the individual mean of absolute values of slopes as

$$\tan \theta = (\tan \theta_1^2 + \tan \theta_2^2)^{1/2}$$
(1.4)

where

$$\tan \theta_{i} = \lim_{L \to \infty} \frac{1}{L} \int_{0}^{L} |y_{i}'| dx; \quad i = 1,2 \quad (1.5)$$

and y' is the slope of the respective surface profiles; P represents the local interface pressure; and H is the hardness of the softer material.

Relation (1.1), as written above, is applicable for contact in a vacuum. One can modify the expression by simply adding to it

$$h_{f} \equiv \frac{\text{conductivity of interstitial fluid}}{\text{average distance between the surfaces}}$$
 (1.6)

in order to account approximately for the presence of the interstitial fluid.

All parameters in relation (1.1), except for the pressure, are functions of the material and geometry and can be easily obtained. The determination of the pressure distribution and the extent of the contact area between two plates present both mathematical and experimental difficulties. From the mathematical point of view, the difficulty stems from the fact that the theory of elasticity will yield a three dimensional (axisymmetric) problem with mixed boundary conditions. Experimentally, the discrimination between contact and gaps of the order of millionths of an inch is required.

Roetscher [2] proposed in 1927, a rule of thumb that the pressure distribution of two bolted plates, Fig.1, is limited to the two frustums of the cones with a half cone angle of 45 degrees as shown in Fig. 2 and that at any level within the cone the pressure is constant. Also, for symmetric plates, according to Roetscher, separation will occur at the circle which is defined by the contact plane and the 45 degree truncated cone emanating from the outer radius of the bolt head.

Since 1961 Fernlund [3], Greenwood [4] and Lardner [5] among others reported solutions based upon the theory of elasticity. Although their solutions also yield separation radii at approximately 45 degrees as in Roetscher's rule, their solutions yield a much more reasonable pressure distribution as compared to Roetscher's constant pressure at each level of the frustrum. These investigators have made use of the Hankel transform method demonstrated by Sneddon [6] in his solution for the elastic stresses produced in a thick plate of infinite radius by the application of pressure to its free surfaces. The basic assumption in their approach is that two bolted plates can be represented by a single plate of the same thickness as the combined thickness of the two plates under the same external loading. It then follows that the z-stress distribution at the parting plane can be approximated by the z-stress distribution in the same plane of the single plate. It also follows that separation will occur at the smallest radius in that plane for which

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the z-stress is tensile. In the case of two plates of equal thickness the  $\sigma_z$  stress at the midplane of the equivalent single plate is the stress of interest.

Fernlund [3], for example, used the method of superposition in the sequence shown in Figs. 3(a) to 3(c) to obtain annular loading. Then by superposition of shear and radial stresses at radius A, Figs. 3(d) and 3 (e), opposite in sign of those due to the annular loading at the free surfaces, Fernlund obtained the solution for a single plate with a hole under annular loading (Fig. 3(f)).

Experimental work in this area included Bradley's [7] measurements of the stress field by three dimensional photoelasticity techniques, and the use of introducing pressurized oil at various radii in the contact zone and measuring the pressure at which oil leaks out from the joint [3,8]. Both of these experimental methods have uncertainties as indicated by the authors.

Because of the cumbersomness of the Hankel transform solution and experimental difficulties, the body of work in this area has been very limited and definite verification of analytical results by experiment is not cited in the literature.

The research described in the succeeding chapters was undertaken with the following primary objectives:

- a) To provide a method of solution for the case of two bolted plates without the simplifying assumption of the single plate substitution.
- b) To devise a test to validate the two plate analysis.
- c) To test the validity of the single plate substitution.

A finite element computer program has been assembled for the analytical solution of two-plate problems. Experiments have been performed to verify the analytical results. Since in heat transfer calculations the extent of the radius of contact is of primary importance, and since by restricting the experimental effort to the verification of only this parameter, (rather than the verification of the entire pressure distribution,) many experimental uncertainties should be eliminated, the experiments were designed only for the determination of the contact area.

Agreement between analysis and experiment was obtained and the results show that the single plate substitution is not justified and the 45 degree rule is not valid for the flat and smooth surfaces studied.

### Chapter II

## ANALYSIS

## A. Problem Statement

The objective of the anlaysis was to solve the linear elasticity problem of two plates in contact defined mathematically by the following equations for each plate:

The equations of equilibrium

$$\frac{\partial}{\partial r} (r\sigma_{r}) - \sigma_{t} + r \frac{\partial \tau}{\partial z} = 0$$

$$\frac{\partial}{\partial r} (r \tau) + \frac{\partial}{\partial z} (r \sigma_{z}) = 0$$
(2.1)

where  $\tau_{rz} = \tau_{zr} = \tau$  and  $\tau_{rt} = \tau_{zt} = \tau_{tz} = 0$ .

The stress - strain relations, using standard notation for stress and strain,

$$\sigma_{r} = \lambda \varepsilon + 2 \mu \varepsilon_{r}$$

$$\sigma_{t} = \lambda \varepsilon + 2 \mu \varepsilon_{t}$$

$$\sigma_{z} = \lambda \varepsilon + 2 \mu \varepsilon_{z}$$

$$\tau = 2 \mu \varepsilon_{rz}$$
(2.2)

where  $\lambda$  and  $\mu$  are Lame's constants and

$$\lambda = \frac{2 G v}{1 - 2 v}$$

$$\mu = G$$
(2.3)

if G is the modulus of elasticity in shear and  $\nu$  is Poisson's ratio; and  $\epsilon$  the volume expansion is defined by

$$\varepsilon = \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z}$$
(2.4)

where u is the displacement in the radial direction and w is the displacement in the axial direction.

The strain - displacement relations

$$\varepsilon_{r} = \frac{\partial u}{\partial r}$$

$$\varepsilon_{t} = \frac{u}{r}$$
(2.5)
$$\varepsilon_{z} = \frac{\partial w}{\partial z}$$

$$\varepsilon_{rz} = \frac{1}{2}(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial r})$$

The above equations can be combined to yield the equilibrium equations in terms of displacements

$$\nabla^{2} \mathbf{u} - \frac{\mathbf{u}}{\mathbf{r}} + \frac{1}{1 - 2\nu} \frac{\partial \varepsilon}{\partial \mathbf{r}} = 0$$

$$\nabla^{2} \mathbf{w} + \frac{1}{1 - 2\nu} \frac{\partial \varepsilon}{\partial z} = 0$$
(2.6)

The applicable boundary conditions are (see Fig. 11)

$$\sigma_{r}^{(1)}(A,z) = \sigma_{r}^{(2)}(A,z) = 0$$

$$\tau^{(1)}(A,z) = \tau^{(2)}(A,z) = 0$$

$$\sigma_{r}^{(1)}(C,z) = \tau^{(2)}(C,z) = 0$$

$$\tau^{(1)}(C,z) = \tau^{(2)}(C,z) = 0$$

$$\tau^{(1)}(r,D_{1}) = \tau^{(2)}(r,-D_{2}) = 0,$$

$$\tau^{(1)}(r,D_{1}) = \tau^{(2)}(r,0), \quad A \leq r \leq R_{0}$$

$$\sigma_{z}^{(1)}(r,D_{1}) = \sigma_{z}(r,-D_{2}) = 0, \quad B \leq r \leq C$$

$$\tau^{(1)}(r,0) = \tau^{(2)}(r,0) = 0, \quad R_{0} \leq r \leq C$$

$$\sigma_{z}^{(1)}(r,0) = \sigma_{z}^{(2)}(r,0), \quad A \leq r \leq R_{0}$$

$$\sigma_{z}^{(1)}(r,0) = \sigma_{z}^{(2)}(r,0) = 0, \quad R_{0} \leq r \leq R$$

$$\sigma_{z}^{(1)}(r,D_{1}) = \sigma_{z}^{(2)}(r,-D_{2}) = P(r), \quad A \leq r \leq R$$

$$\sigma_{z}^{(1)}(r,D_{1}) = \sigma_{z}^{(2)}(r,0), \quad A \leq r \leq R$$

$$\sigma_{z}^{(1)}(r,0) = w^{(2)}(r,0), \quad A \leq r \leq R$$

$$w^{(1)}(r,0) = w^{(2)}(r,0), \quad A \leq r \leq R_{0}$$

$$2\pi \int_{A}^{B} \Pr dr = 2\pi \int_{A}^{R_{o}} \Pr dr$$

Inspection of the above equations shows that the above constitutes a mixed boundary value problem and the most appropriate technique for solution is the finite element method.

#### B. Method of Analysis

A finite element computer program was assembled for the analytical solution of bolted plates. Descriptions of the finite element method are given in references [9,10], but for completeness, an outline of the mathematical formulation for this case is presented in Appendix A. A listing of the cumputer program and instructions for its use may be found in Appendix B. Appendix C contains user's instructions and a listing of the finite element program modified to include thermal strains.

As in the previous work axial symmetry and isotropic linear elastic material behavior were assumed. However, the computer programs accommodate plates with different material properties in a bolted pair.

The basic concept of the finite element method is that a body may be considered to be an assemblage of individual elements. The body then consists of a finite number of such elements interconnected at a finite number of nodal points or nodal circles. The finite character of the structural connectivity makes it possible to obtain a solution by means of simultaneous algebraic equations. When the problem, as is the case here, is expressed in a cylindrical coordinate system and in the presence of axial symmetry in geometry and load, tangential displacements do not exist, and the three-dimensional annular ring finite element is then reduced to the characteristics of a two-dimensional finite element.

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The analysis consists of (a) structural idealization, (b) evaluation of the element properties, and (c) structural analysis of the assemblage of the elements. Items (b) and (c) are covered in the appendices and in the references quoted. The structural idealization and the criteria for acceptable solutions will be described in this chapter.

Fig. 4(a) shows two circular plates in contact under arbitrary axisymmetric loading. The plates are subdivided into a number of annular ring elements which are defined by the corner nodal circles (or node points when represented in a plane) as shown in Figs. 4(b) and 4(c). Unlike the cases described in Chapter I, which have been solved by the Hankel transform method, all plates solved by the finite element method have finite radii. The cross sections of each annular ring element is either a general quadrilateral or triangle. To improve accuracy smaller elements are used in zones where rapid variations in stress are anticipated than in zones of constant stress; thus the different size elements shown in Fig. 4(b). (However, the total number of elements allowable are subject to computer capacity.)

Figure 4(b) shows the two plates in contact for the radial distance  $X_c$  and separated beyond it. It is to be noted that the nodal points on the parting line and within the length of contact  $X_c$  are common to elements in both plates. The other elements adjacent to the parting line on each plate are separated from their corresponding elements in the mating plate and these elements have no common nodal points. Physically, it is equivalent to the welding together of the two plates in the contact zone. Mathematically, we are imposing the condition that

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in the contact zone the displacements in the z and r directions be identical for both plates. In the case of bolted plates of equal thickness, i.e. in the presence of symmetry about the parting plane, these conditions apply exactly. Furthermore, because of this symmetry, one needs to analyze only one plate, as shown in Fig. 5(b), with the imposed boundary conditions on the contact zone of zero displacement in the z-direction and freedom to displace in the r-direction. It can also be observed that the solution of two plates with symmetry about the parting plane is equivalent to the solution of one of these plates under the same loading conditions, but resting on a frictionless infinitely rigid plane. Also, under the above conditions the shear stress in the contact zone is identically zero.

In the case of bolted plates of unequal thickness the model includes both plates as shown in Fig. 5(c). This model is an approximation because, in general, two plates of unequal thickness do not have the same displacement in the r-direction on the contact surface. The solution yields, therefore, a shearing stress distribution in the contact zone. The solution, however, should be exactly compatible with the physical model if the frictional forces in the joint prevent sliding.

The critical aspect of the approach used herein is the determination of the largest nodal circle on the parting plane which is common to an element on each plate. This nodal circle defines the contact zone and the radius,  $R_{o}$ , at which separation occurs.

The output of the finite element computer program includes the displacement of each node in the r and z directions and the average

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 $\sigma_z, \sigma_r, \sigma_t$  and  $\tau_rz$  stresses for each element.

The computation is iterative and the objective is to achieve the lowest possible compressive  $\sigma_z$  stress in the outermost elements bordering the contact zone. Unacceptable solutions are shown in Fig. 6(a) and 6(b). If  $R_{a}$  for a given external load distribution is too small, then the solution will show that the two plates intersect (Fig. 6(a)). On the other hand, if  $R_{o}$  is assumed too large, the solution will show that the outer portion of the contact zone sustains a tensile  $\sigma_z$  stress (Fig. 6(b)). Neither of these two situations is physically feasible. In general, the procedure employed was to commence the iterations with a value for  $R_{o}$  which would yield a tensile  $\sigma_{z}$  stress in the outer elements adjacent to the contact zone and then move R inward. The contact zone. For example, for the case shown in Fig. 5(b), if the  $\sigma_{z}$ stress for the element in the last row and to the left of the last roller is tensile, then the following iteration will proceed without the last roller. Thus, the resolution is one nodal interval. Finer resolution can be obtained by reducing the interval between nodal circles by introducing more elements or shifting the grid locally. The same criteria apply to the model shown in Fig. 5(c).

In the finite element analysis of the Fernlund (3) model, i.e. single plate with external loads at the faces  $z = \pm D$  no iteration is required and the rollers shown in Fig. 5(c) would extend to the outer radius of the plate. (Although Fernlund's computations are based on infinite plates, computations show that there is no distinction between infinite plates and plates of radius greater than five times of the outer

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radius, B, of the load. See Fig. 5(a).

Convergence was tested by subdividing elements further, with nodal points in the coarser grid remaining nodal points in the finer grid. Changing the mesh from 180 elements to 360 elements have shown no improvement in accuracy. Meshes from 180 to 300 elements were used in this analysis. Typical spacings between nodal points were 0.015 inch radially and 0.03 inch in the z-direction.

#### Chapter III

#### EXPERIMENTAL METHOD

The objective of the experiment was to determine the extent of contact between two plates when bolted together. Sixteen type 304 stainless steel plates, 4 inches in diameter, were machined to nominal thicknesses of 1/16, 1/8, 3/16 and 1/4 inch, 4 plates for each thickness. After rough machining these plates were stress relieved at  $1875^{\circ}F$  and ground flat to 0.0002 inch. One side of each plate was then lapped flat to better than one fringe of sodium light (11 micro-inches) in the case of the 1/8, 3/16 and 1/4 inch plates, and to better than two fringes in the case of the 1/16 inch plates. Disregarding scratches, the finish of the lapped surfaces was 5 microinches rms. Each plate had a central hole, 0.257 inch in diameter, for a 1/4 - 20 bolt, and two notches and two holes on the periphery (see Fig. 7). Two techniques were employed in determining the area of contact when two of these plates were bolted together. The first technique entailed the following procedure (see Fig. 7):

- (a) The plates were cleaned with alcohol and lens tissue.
- (b) One plate was placed on the base of the fixture shown in Fig.7, lapped surface up and the two holes on the periphery of the plates engaged with two pins on the fixture. Spacers between the fixture base and plate prevented the pins from extending beyond the top surface of the plate.

- (c) A second plate was placed on top of the first plate, lapped surfaces mating. The notches on the two plates were lined up with each other and with notches in the base of the fixture. Thus, rotation of the plates was prevented.
- (d) A standard 1/4 20 hex-nut with its annular bearing surface (0.42 inch 0.D.) lapped flat was engaged on a high strength 1/4 - 20 bolt. The nut was located about two threads away from the head of the bolt and served in lieu of the bolt head. The lapped surface of the nut faced away from the bolt head and since the nut was not sent home against the bolt head, the looseness of fit between nut and bolt offered a degree of self alignment.
- (e) The bolt and nut assembly described in (d) above was then inserted through the 1/4 inch central holes of the two plates and a second 1/4 - 20 lapped nut was engaged on the bolt. Thus the two plates were captured by the two 1/4 -20 nuts with the lapped surfaces of the nuts bearing against the plates.
- (f) With the torque wrench shown on the right in Fig. 7, the nuts were torqued down to 70 pound-inches of torque to yield a 1100 pound force in the bolt [11].
- (g) The position of the keys was changed to engage with only the lower plate and the fixture and a special spanner wrench, as shown in Fig. 7, was engaged with the top plate. The spanner wrench was restrained to move in the horizontal plane and it was set into motion by the screw pressing against the wrench handle.

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 (h) With the aid of the spanner wrench the upper plate was rotated relative to the lower plate several times approximately + 5 degrees.

Thus, the above procedure allowed for the rubbing of one plate relative to its mate while under a bolt force of approximately 1100 lbs. The remaining steps were the disassembly and the measurement of the extent of the contact zone which was defined by the shine due to the rubbing in the contact zone. It is to be noted that the boundaries of the contact zone as measured by the naked eye and by searching for marks of "polished" or "damaged" surface under a 10.5 power magnification are essentially the same.

The above test was performed on 5 pairs of specimen. These were 1. One 0.07 in. plate mated to a 0.65 in. plate 2. One 0.126 in. plate mated to a 0.126 in. plate 3. One 0.191 in. plate mated to a 0.192 in. plate 4. One 0.253 in. plate mated to a 0.256 in. plate 5. One 0.124 in. plate mated to a 0.257 in. plate The identical tests were repeated for

1. One 0.124 in. plate mated to a 0.126 in. plate; and

2. One 0.191 in. plate mated to a 0.192 in. plate,

but in lieu of the 1/4 - 20 nuts in direct contact with the plates special washers, 1.000 in. 0.D., 0.257 in. I.D. and 0.620 in. high, were interposed between the bolt head and nut.

The diameters of the contact zones were measured with a machinist ruler with 100 divisions to the inch and with a Jones and Lamston Vertac 14 Optical Comparator.

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The second technique used the same parts and fixture, but it involved autoradiographic measurements.

Four plates, 1/4, 3/16, 1/8 and 1/16 inch thick were sent to Tracerlab, Inc., Waltham, Mass., for electrolytic plating with radioactive silver Ag 110<sup>M</sup> (half life of 8 months). Each plate was masked except for an area on the lapped face one inch in radius. The plates then received a plating of copper about 5 microinches thick and then approximately a 5 microinch plating of silver containing the radioactive isotope. The resultant activity on each plate was about 2 millicuries.

These plates were then mated to plates of equal thickness (not plated) and assembled in a shielded hood as indicated in steps (a) to (h) above except that in the case of the pair of 1/4 inch plates care was taken not to rotate the plates during and after assembly and in the remaining cases the rotation specified in step (h) was done only once in one direction.

The plates were then disassembled and the radioactive contamination on the plates which were in contact with the radioactive plates measured. The transferred activity was:

1/4 in. plate approximately 0.05 microcuries
3/16 in. plate approximately 3. microcuries
1/8 in. plate approximately 0.1 microcuries
1/16 in. plate approximately 0.4 microcuries

It was also observed in handling that the adhesion of the silver on the 3/16 in. plate was poor.

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Kodak type R single coated industrial x-ray film was then placed on the contaminated plates under darkroom conditions. The sensitive side of the film was pressed against the radioactive sides of the plates with a uniform load of about five pounds and left for exposure for three days. After three days, the film was removed and developed. The results are shown in Fig. 10.

#### Chapter IV

#### RESULTS

A. Pressure Distribution and Radii of Separation from Single Plate and Two Plate Finite Element Models.

Using the finite element procedure described in Chapter II, the midplane stress distribution of <u>single</u> circular plates of thickness 2D, outer radii of 1.54 in., inner radii of 0.1 in., Poisson ratio of 0.3, and loaded by a constant pressure between radii A and B, Fig. 3(f), was computed. Computations were performed for D values of 0.1, 0.1333 and 0.2 in. For each value of D the radius B, which defines the region of the symmetric external load, assumed the values of 0.31, 0.22, 0.16 and 0.13 in. The  $\sigma_z$  stress distribution at the midplane, from the inner radius to the radius at which the above stress is no longer compressive, is shown in Figs. 12, 13 and 14 as a function of radius.

The identical cases were then recomputed, using again the finite element method, in accordance with the <u>two plate</u> model shown in Figs. 4(b) and 5(b). These results are given in Figs. 15, 16 and 17.

Inspection of the above figures show that the two plate model yields a somewhat different stress distribution in the contact zone than the stress distribution approximated from the single plate model, and more significantly, from the heat transfer point of view, the two plate model yields a lower value for the radius of separation,  $R_o$ , which

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results in a reduction in area for heat transfer. Table 1 gives a comparison of the values for  $R_{o}$  obtained from the two models.

It may be observed that the single plate result of Fernlund (Ref. 3, pp. 56, 124) is in fair agreement with the finite element results obtained for the single plate model.

B. Radii of Separation from Experiment and Their Predicted Values from the Two Plate Finite Element Computation.

As described in Chapter III, stainless steel circular plate specimen (Fig. 7) were bolted together, rotated relative to each other with the bolt force acting, and after disassembly the contact area of the joint was determined by measuring the footprints (the shiny, polished areas) on each plate due to the plates rubbing against each other. Photographs of these footprints are shown in Fig. 8. Fig. 9 also shows a typical footprint of the annular bearing surface of the 1/4 - 20 nut against a plate. All plates tested were of 304 stainless steel, 4 inch 0.D., .257 I.D., and the nominal thicknesses of the plates were 1/16, 1/8, 3/16 and 1/4 inch. In addition to the plates fastened with standard nuts which gave a loading circle of radius B (Fig. 5) of 0.211 inch, plates fastened by the special nuts described in Chpater III for which B was 0.5 inch were also tested.

Figure 10 shows the results of the autoradiographic tests described in Chapter III. For all plate pairs tested, i.e. 1/16, 1/8, 3/16 and 1/4 inch nominal, the value of B was 0.211 inch.

The pressure distributions and radii of separation for all the

- 29 -

above test cases were computed independently by the two plate model finite element analysis. Table 2 gives the test and analytical results for all test cases. The test results are an average of all measurements (minimum of six readings). A description of the analyses follows.

Figure 18 shows the results of a two plate and a single plate model analysis for the 0.253 inch bolted test specimen. For Figure 19 the external pressure distribution between radii A and B is triangular. (The total force, however, is equal to the force exerted in the case of uniform pressure.) In one case, the peak external pressure is at A, Fig. 20(a), and in the other case at B, Fig. 20(b). Results of another computation which assumed a uniform displacement of 50 microinches under each nut is shown in Fig. 21. It is interesting to note that the point of separation obtained by using the two plate model for all variations of loading given above occurs in the range of r/Avalues of 2.73 to 2.93 while the two plate model yields separation at a value for r/A of 3.5. The computed deflections under the nuts are given in Fig. 22.

The finite element analysis results for the 0.191 in. plate pair specimen are given in Fig. 23. Figures 24 and 25 show the computed pressure distribution and deflection patterns in the joint, respectively, for the 1/8 in. plate pair. In order to investigate the possible influence misalignments of the spanner wrench, i.e. vertical forces or restraints exerted at edge of plate, may have on the results of the experiment, the extreme case of fixing the outer edges of the plate as shown in Fig. 20(c) was considered. As Fig. 24 shows, within the

- 30 -

resolution of the finite element grid size, the effect is negligible. This model, Fig. 20(c), and result also indicate that the influence of additional fasteners 2 inches away would not have an influence on the contact zone for the geometry considered. (However, if the distance between bolts is considerably reduced, then the contact area should increase.) The computed results for the 1/16 inch plate pair is given in Fig. 26.

Figure 27 gives the finite element analysis results for the asymmetric case of a 1/8 in. plate bolted to a 1/4 in. plate. The model shown in Fig. 5(c) was used and as discussed in Chapter II, this model is strictly valid only if the friction in the joint prevents sliding between the plates. Nevertheless, the percent discrepancy between the computed value and tested value (see Table 2) falls within the range of the symmetric cases analyzed and tested.

In summary, the results obtained from the two plate finite element model and from experiment are in good agreement (Fig. 28).

#### Chapter V

#### APPLICATION

An application of the above results for the evaluation of the thermal contact conductance,  $h_c$ , and the determination of the heat transferred in a specific, but typical, lap joint section is illustrated in this chapter.

An aluminum lap joint in a vacuum environment, the relevant section and boundary conditions as shown in Fig. 29, was analyzed by means of a nodal analysis. The plate thickness was 0.1 in. and the hole diameter, 2A, was 0.2 in. The bearing surface of the bolt, 2B, was 0.26 in. in diameter. Because of the high conductivity and small thickness of the plates, no z dependence (see Fig. 29) was assumed for the temperature in the main body of the plate. However, heat flow in the z-direction in the nodes above and below the contact zone is considered. Qualitatively, the heat flow in the joint proceeds in the x-y plane from the left end (Fig. 29) toward the 0.2 in. diameter hole. In the vicinity of the hole, a macroscopic constriction for heat flow is encountered because the flow is being channeled toward the small contact zone. The flow of heat then encounters the microscopic constrictions at the contacting asperities (which determine  $h_c$ ) in the contact zone; spreads out in the x-y directions in the second plate; and continues to the right edge of the lap joint.

The material properties assumed were (refer to equation 1.1):

H = 150,000 psi  
k = 100 Btu/hr-°F-ft (k<sub>1</sub> = k<sub>2</sub> = 100)  

$$\sigma$$
 = 5.9 x 10<sup>-6</sup> ft. ( $\sigma_1 = \sigma_2 = 50 \times 10^{-6}$ in.)  
tan  $\theta$  = 0.1

Assuming further, a uniform load of 46,500 psi on the loading surface (#10 screw; 1000 lb. bolt force) and referring to Fig. 15, curve  $\frac{B}{A} = 1.3$ , the following interface stresses,  $\sigma_z$ , contact heat transfer coefficient,  $h_c$ , and conductance, (area) ( $h_c$ ), were obtained as a function of inner and outer radii. (These radii define increments of area, the sum of which define one quarter of the contact zone.):

| router | rinner | $\sigma_z$ | h<br>c           | Area x h                  |
|--------|--------|------------|------------------|---------------------------|
| inch   | inch   | psi        | $Btu/hr-°F-ft^2$ | Btu/hr-°F-ft <sup>2</sup> |
|        |        |            |                  |                           |
| .13    | .1     | 27,900     | 446,000          | 16.6                      |
| .16    | .13    | 14,000     | 223,000          | 10.6                      |
| .175   | .16    | 3,950      | 63,100           | 1.7                       |

The conductance between nodal points were then computed and with the aid of the steady state heat transfer program listed in Appendix D, the nodal temperatures for the conditions given in Fig. 29 were computed. The heat transferred from the edge maintained at  $20^{\circ}$ F to the edge at  $0^{\circ}$ F (Fig. 29) for this case was 2.88 Btu/hour. The same computation was repeated for the case of a bearing surface between the plate and the bolt (2B) of 0.44 in. in diameter, but the bolt force was left unchanged. The heat transferred from the  $20^{\circ}$ F edge to the  $0^{\circ}$ F edge in this case was 3.15 Btu/hour. In the absence of the joint the heat transfer along an equivalent 7 inch length of solid aluminum would have been 3.58 Btu/hour. This data shows that the thermal resistance of the contact zone (not entire 7 inch lap joint) was decreased from 1.52 to 0.92 °F-hr/Btu by the increase of the effective bolt head diameter from .26 to .44 in. It should be observed that the change in thermal resistance of the joint is primarily due to the increase in contact area and the resulting decrease in macroscopic constriction resistance at the hole. Also, the heat flux in this example is mainly controlled by the 7 inch length and 0.1 inch thickness rather than the joint resistance. This emphasizes the importance of a balanced thermal design.

For large heat fluxes where thermal strains may have an influence on the radii of separation, the finite element program given in Appendix C may be used. Also, in a non-vacuum environment the effect of the interstitial fluid is added in two ways. Firstly, equation (1.6) is applied to account for the presence of interstitial fluid in the contact zone, and secondly, conduction across the gaps between the plates and convection from the plates is considered. (Radiation heat transfer, if applicable, should also be included.)

### Chapter VI

## CONCLUSIONS

The finite element technique used in this work for the analysis of the pressure distribution and deformation of smooth and flat bolted plates under conditions of axial symmetry predicts contact areas in joints considerably lower than reported previously in the literature. These results were verified experimentally. The discrepancy between the previously reported results and the results reported here is due to the simplifying assumption made by earlier researchers that a joint can be modeled as a single plate.

The computer programs listed in the appendices will also accommodate joints made up of plates of dissimilar materials and the presence of thermal gradients.

Of the eleven tests performed, only one (case 3, autoradiographic) yielded inconsistent results. (This data point could probably be ignored because of the poor adhesion of the plating material which manifested itself by the high radioactive contamination count during test.)

The finite element analysis performed for the test specimen show that the gap between the 1/4 inch bolted steel specimen is 98.6 microinches at the outer radius of the plate of 2 inches, and 1/32of an inch away from the radius of separation (0.35 in.), the gap is only 3 microinches for the test load. This data indicates the difficulties previous workers have encountered in their experiments. (This also explains the oval shape of several of the footprints.) Furthermore, this data shows that the effects of surface roughness and the lack of flatness could have a significant effect on the size of contour area.

An application of the above work to a heat transfer problem is illustrated in Chapter V.

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#### APPENDIX A

## FINITE ELEMENT ANALYSIS OF AXISYMMETRIC SOLIDS

The finite element method and the equations which govern the stresses and displacements in axisymmetric solids is given in the literature [9,10,12,13,15] and the procedure will be briefly summarized in this appendix.

The procedure for the standard stiffness analysis method is as follows [15]:

(a) The internal displacements, v, are expressed as

$$\{\mathbf{v}(\mathbf{r},\mathbf{z})\} = [\mathbf{M}(\mathbf{r},\mathbf{z})] \{\alpha\}$$
(A.1)

where M is a displacement function and  $\alpha$  are the generalized coordinates representing the amplitudes of the displacement functions.

(b) The nodal displacements v are expressed in terms of the generalized coordinates

 $\{\mathbf{v}_{\mathbf{i}}\} = [\mathbf{A}] \{\alpha\} \tag{A.2}$ 

where A is obtained by substituting the coordinates of the nodal points into M.

(c) The generalized coordinates are expressed in terms of the nodal displacements

$$\{\alpha\} = [A]^{-1} \{\mathbf{v}_i\}$$
(A.3)

(d) The element strains,  $\varepsilon$ , are evaluated

$$\{\varepsilon\} = [B(\mathbf{r}, \mathbf{z})] \{\alpha\}$$
(A.4)

where  $\ensuremath{\mathtt{B}}$  is obtained from the appropriate differentiation of  $\ensuremath{\mathtt{M}}.$ 

(e) The element stresses are expressed in terms of the stress-strain relation  $\ensuremath{\mathtt{D}}$ 

$$\{\sigma(\mathbf{r}, \mathbf{z})\} = [D] \{\varepsilon\} = [D] [B] \{\alpha\}$$
 (A.5)

(f) Assuming a virtual strain  $\overline{\epsilon}$  and a generalized virtual coordinate displacement  $\overline{\alpha}$  the internal virtual work,  $W_{i}$ , in the differential volumn, dV, is given by

$$dW_{i} = \{\epsilon\}^{T} \{\sigma\} dV = \{\alpha\}^{T} [B]^{T} [D] [B] \{\alpha\} dV \qquad (A.6)$$

and the total internal virtual work is

$$W_{i} = \{\overline{\alpha}\}^{T} \left[ \int_{V_{0}1} [B]^{T} [D] [B] dV \right] \alpha \qquad (A.7)$$

(g) The external work,  $W_e.$  associated with the generalized displacement  $\overline{\alpha}$  is

$$W_{e} = \{\alpha\}^{T} \{\beta\}$$
(A.8)

where  $\beta$  are generalized forces corresponding with the displacements  $\alpha$ .

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(h) After equating W and W and setting the  $\overline{\alpha}$  displacement to unity

$$\{\beta\} = \left[\int_{Vol} [B]^{T} [D] [B]\right] \alpha = \left[\overline{k}\right] \{\alpha\}$$
 (A.9)

where 
$$[\overline{k}] = \int_{Vol} [B]^T [D] [B] dV$$
 (A.10)

and which transforms to the nodal point surfaces

$$k = [A^{-1}] [\overline{k}] [A^{-1}]$$
 (A.11)

(i) The stiffness matrix for the complete system is then

$$\begin{bmatrix} K \end{bmatrix} = \sum_{m=1}^{n} \begin{bmatrix} k \end{bmatrix}_{m}$$
(A.12)

where n equals the number of elements and the equilibrium relationship becomes

$$\{Q\} = [K] \{v_i\}$$
 (A.13)

where

$$\{Q\} = \sum_{m=1}^{N} \{R\}_{m}$$
(A.14)

{R} = 
$$\int_{\text{Area}} [A^{-1}]^{\text{T}} [M]^{\text{T}} \{P\}_{\text{m}} dA$$
 (A.15)

and P are the surface forces.

The above procedure applies with minor modification to problems with thermal and body force loading.

The expression

$$\{Q\} = [K] \{v_i\}$$
 (A.16)

represents the realtionship between all nodal point forces and all nodal point displacements. Mixed boundary conditions are considered by rewriting this equation in the partitioned form

$$\left\{ \begin{array}{c} Q_{a} \\ \hline Q_{b} \end{array} \right\} = \left[ \begin{array}{c} K_{aa} \\ \hline K_{ba} \\ \hline K_{ba} \end{array} \right] \left\{ \begin{array}{c} u_{a} \\ \hline K_{bb} \\ \hline \end{array} \right\} \left\{ \begin{array}{c} u_{a} \\ \hline u_{b} \\ \hline \end{array} \right\}$$
(A.17)

where  $v_i = u$ .

The first part of the partitioned equation can be written as

$$\{Q_a\} = [K_{aa}] \{u_a\} + [K_{ab}] \{u_b\}$$
 (A.18)

and then expressed in the reduced form

$$\{Q^*\} = [K_{aa}] \{u_a\}$$
 (A.19)

where

$$\{q^*\} = \{Q_a\} - [K_{ab}] \{u_b\}$$
 (A.20)

The matrix equation (A.19) is solved for the nodal point displacements by standard techniques. Once the displacement are known the strains are evaluated from the strain displacement relationship and the stresses in turn are evaluated from the stress strain relations.

Both triangular and quadrilateral elements are used. The displacements in the r-z plane in the element are assumed to be of the form

$$\mathbf{v}_{\mathbf{r}} = \alpha_1 + \alpha_2 \mathbf{r} + \alpha_3 \mathbf{z}$$
(A.21)
$$\mathbf{v}_{\mathbf{r}} = \alpha_4 + \alpha_5 \mathbf{r} + \alpha_6 \mathbf{z}$$

This linear displacement field assures continuity between elements since lines which are initially straight remain straight in their displaced position. Six equilibrium equations are developed for each triangular element.

A quadrilateral element is composed of four triangular elements and ten equilibrium equations correspond to each element.

# APPENDIX B

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# FINITE ELEMENT PROGRAM FOR THE ANALYSIS OF ISOTROPIC

# ELASTIC AXISYMMETRIC PLATES (ref. 13,14)

# Input Instructions:

| Card<br>Sequence | Item  | Format | Columns |  |  |  |  |  |  |  |  |
|------------------|---|--------|---------|--|--|--|--|--|--|--|--|
| 1                | Title   | 18A4   | 1-72    |  |  |  |  |  |  |  |  |
| 2                | Total number of nodal points  | 15     | 1-5     |  |  |  |  |  |  |  |  |
|                  | Total number of elements  | 15     | 6-10    |  |  |  |  |  |  |  |  |
|                  | Total number of materials   | 15     | 11-15   |  |  |  |  |  |  |  |  |
|                  | Normalizing stress (NORM)   | 15     | 16-20   |  |  |  |  |  |  |  |  |
|                  | Number of pressure cards  | 15     | 21-25   |  |  |  |  |  |  |  |  |
| 3                | <pre>(If NORM = 0, put in value of E in material card;<br/>if NORM = 1, put in value E/σ<br/>vertical;<br/>if NORM = -1, put in value E/σ<br/>octahedral;<br/>NOTE: Use NORM = 0 for this application.)<br/>(Material property cards - one set of<br/>(a) and (b) for each material)<br/>(a) 1st card</pre> |        |         |  |  |  |  |  |  |  |  |
|                  | Material No.  | 15     | 1-5     |  |  |  |  |  |  |  |  |
|                  | Initial $\sigma_z$ stress   | F10.0  | 6-15    |  |  |  |  |  |  |  |  |
|                  | Initial $\sigma$ stress r   | F10.0  | 16-25   |  |  |  |  |  |  |  |  |
|                  | (b) Second Card   |        |         |  |  |  |  |  |  |  |  |
|                  | Е   | F10.0  | 1-10    |  |  |  |  |  |  |  |  |
|                  | ν   | F10.0  | 11-20   |  |  |  |  |  |  |  |  |

| Card<br>Sequence | Item   | Format                  | Column  |
|------------------|--|-------------------------|---|
| 4                | Nodal point information (One for each node)                                | 215,4F10.               | 0   |
|                  | Node number<br>CODE<br>r-coordinate<br>z-coordinate<br>XR<br>XZ            |                         | 1-5<br>6-10<br>11-20<br>21-30<br>31-40<br>41-50 |
| If               | the number in column 10 is   | Condition               | <u>1</u>  |
| 0                | XR is the specified R-load and<br>XZ is the specified Z-load               | free                    |   |
| 1                | XR is the specified R-displacement and XZ is the specified Z-load          | $\langle \! \! \rangle$ |   |
| 2                | XR is the specified R-load and XZ is the specified Z-displacement.         | nn.                     |   |
| 3                | XR is the specified R-displacement and XZ is the specified Z-displacement. | fixed                   |   |

# Remarks

The following restrictions are placed on the size of problems which can be handled by the program.

| Item                    | Maximum Number |
|-------------------------|----------------|
| Nodal Points            | 450            |
| Elements                | 450            |
| Materials               | 25             |
| Boundary Pressure Cards | 200            |

All loads are considered to be total forces acting on a one radian segment. Nodal point cards must be in numerical sequence. If cards are omitted, the omitted nodal points are generated at equal intervals along a straight line between the defined nodal points. The boundary code (column 10), XR and XZ are set equal to zero.

If the number in columns 6-10 of the nodal point cards is other than 0, 1, 2 or 3, it is interpreted as the magnitude of an angle in degrees. The terms in columns 31-50 of the nodal point card are then interpreted as follows:

XR is the specified load in the s-direction

XZ is the specified displacement in the n-direction The angle must always be input as a <u>negative angle</u> and may range from -.001 to -180 degrees. Hence, +1.0 degree is the same as -179.0 degrees. The displacements of these nodal points which are printed by the program are

> $u_r$  = the displacement in the s-direction  $u_r$  = the displacement in the n-direction

Element cards must be in element number sequence. If element cards are omitted, the program automatically generates the omitted information by incrementing by one the preceding I, J, K and L. The material identification code for the generated cards is set equal to the value given on the last card. The last element card must always be supplied.

Triangular elements are also permissible; they are identified by repeating the last nodal point number (i.e. I, J, K, K).

One card for each boundary element which is subjected to a normal pressure is required. The boundary element must be on the left as one

progresses from I to J. Surface tensile force is input as a negative pressure.

Printed output includes:

1. Reprint of input data.

2. Nodal point displacement

3. Stresses at the center of each element.

Nodal point numbers must be entered counterclockwise around the element when coding element data.

The maximum difference between the nodal point numbers on an element must be less than 25. However, on a nodal diagram elements and nodes need not be numbered sequentially.

Listing:

| ပ      | ****   | 000      |
|--------|--|----------|
| J      | INITE ELEMENT PROGRAM FOR T  | FENT0002 |
|        | RFF FFAST 1.3 SAAS 2   | FENT0003 |
| ى ر    | >、1、1、1、1、1、1、1、1、1、1、1、1、1、1、1、1、1、1、                                   | FNT000   |
|        |  | ENTOOC   |
| 2      | MPLICIT REAL *8 (A-H.  | ENTOOO   |
|        | WPLICIT INTEGER*2(I-N)   | FENT0007 |
|        | STTOP.HED(18), SIGIR(25), SIGI7(25),                                     | FENT0008 |
|        | DEPTH(25).E(10,25).SIG(7).R(450).Z(450).UR(                              | ENTOOD   |
|        | )).STUTAL(450.4).KSW   | ENTOOL   |
|        | COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NE                                    |          |
|        | /ARG/ RRR(5).722(5).S(10.10).P(10).LM(4).DD(3.3                          | NT001    |
|        | HH(6.10).RR(4).ZZ(4).C(4,4).H(6.10).D(6.6).F(6.10).TP(                   | ENT001   |
|        | IX(450,5)  | ENT001   |
|        | JMMCN /BANARG/ B(900),A(900,54),MBAN                                     |          |
|        | DMMON/PRESS/ IBC(200), JBC(200), PR(                                     | ENT001   |
|        | ATA STRS / ******/   | ENTCO1   |
| J      | 1.不敢敢敢敢敢敢敢敢敢敢敢   | ENTOOI   |
| C      | ID PRINT CONTR   | ENT001   |
| ن<br>ن | 林林林 法 大学 医子子 医外外外 医子子 化合金 医子子 化合金 医子子 医子子 医子子 医子子 医子子 医子子 医子子 医子子 医子子 医子 | ENT002   |
|        | EAD (5,1000,EN   |          |
|        | E (6,2000) HED   | ENT002   |
| с<br>С |  | T002     |
|        | EAD(5.1001)  | ENT002   |
|        |  | ENTOC2   |
|        | F (NORM) 65  |          |
|        | AITE (6.204)   | NT002    |
|        | 安徽水水水水水水水水水水水  | FENT0028 |
| C      | EAD AND PRINT  | FENT0029 |
| C      | · · · · · · · · · · · · · · · · · · ·                                    | FENT0030 |
|        | INUE   | ENT0031  |
| ں      |  | EN1003   |
|        | 80 M=1 • NUMM/   | ENTOO    |
|        | AD (5.1002) MTYPE. SIGIZ(MTYPE)  | EN1003   |
|        | MTYPE.SIGIZ(MTYP   | NT003    |
|        | AD (5.1003) (E(J.MTY   | FENT0036 |

FENT0056 FENT0058 FENT0059 FENT0060 FENT0064 **FENT0065 FENT0066** FENT0068 FENT0069 FENT0070 FENT0038 FENTO039 FENT0040 FENT0044 FENT0045 FENT0046 FENT0049 FENT0052 FENT0054 FENT0055 FENT0063 FENT0067 FENT0071 FENT0072 FENT0037 FFNT0042 FENT0043 FENT0048 FENT0050 FENT0053 FENT0057 FENT0061 FENT0062 FENTOC41 FENT0047 FENT0051 \*\*\*\*\*\*\*\*\*\*\*\* WRITE (6.2014) (K.ICODE(K).R(K).Z(K).UR(K).UZ(K).K=NL.N) RFAD (5,1006) N.ICODE(N),R(N),Z(N),UR(N),UZ(N) READ AND PRINT ELEMENT PROPERTIES WRITE (6.2051) (E(J.MTYPE).J=1.2) READ AND PRINT NODAL POINT DATA READ (5,1007) M,(IX(M,I),I=1,5) IF (NUMNP-N) 113.120.105 [F (L.EQ.0) GO TO 110 F (M-N) 170.170.150 F (N-L) 113.112.111  $T \times (N \cdot 1) = I \times (N - 1 \cdot 1) + 1$ [X(N,2) = IX(N-1,2)+1 $I \times (N, 3) = I \times (N-1, 3) + I$ XZ/(())Z-(N)Z)=ZG DR=(R(N)-R(L))/ZX WRITE (6.2015) N R (L)=R(L-1)+DR Z(L) = Z(L-1) + 0ZWRITE (6.2016) WRITE (6.2013) 1 CODE(L) = 0UZ(L)=0.0 G0 T0 110 UR(L) = 0.0G0 T0 900 CONTINUE NL=L+1Z X=N-L [+]=] I + N = N0=7 0 106 110 111 112 113 120 130 140 150 080 100 105 000  $\cup \cup \cup$ 

|    |             | $I \times (N, 4) = I \times (N-1, 4) + 1$         | FENT0073 |
|----|-------------|---|----------|
|    |             | $I \times (N \cdot 5) = I \times (N - 1 \cdot 5)$ | FENT0074 |
|    | 170         | WRITE (6,2017) N, (IX(N,I), I=1,5)                | FENT0075 |
|    | 170         | IF (M-N) 180,180,140                              | FENT0076 |
|    | 190         | IF (NUMEL-N) 300,300,130                          | FENTOO77 |
| С  | 100         | ***************************************           | FENTOC78 |
| C  |             | READ AND PRINT THE PRESSURE CARDS                 | FENT0079 |
| C  |             | ***************************************           | FENT0080 |
| C  | 300         | IF(NUMPC) 290,210,290                             | FENT0081 |
|    |             | WRITE(6,9000)                                     | FENT0082 |
|    | 2 7 1       | DG 200 L=1.NUMPC                                  | FENT0083 |
|    |             | READ(5,9001) IBC(L), JBC(L), PR(L)                | FENTO084 |
|    | 200         | WRITE(6,9002) IBC(L), JBC(L), PR(L)               | FENT0085 |
|    |             | CONTINUE  | FENT0086 |
| С  | <i>x</i> 10 | ***************************************           | FENT0087 |
| Ċ  |             | DETERMINE PAND WIDTH                              | FENT0088 |
| Ċ  |             | *******   | FENTO089 |
| ., |             | 0=L   | FENT0090 |
|    |             | DO 340 N=1.NUMEL                                  | FENT0091 |
|    |             | DO 340 I = 1.4                                    | FENT0092 |
|    |             | DO 325 L=1.4                                      | FENT0093 |
|    |             | KK = IX(N, I) - IX(N, L)                          | FENT0094 |
|    |             | IF $(KK \cdot LT \cdot O) KK = -KK$               | FENT0095 |
|    |             | TF (KK.GT.J) J=KK                                 | FENT0096 |
|    | 325         | CONTINUE  | FENT0097 |
|    |             | CONTINUE  | FENT0098 |
|    |             | $MBAND = 2 \times J + 2$                          | FENTO099 |
| С  |             | *****   | FENT0100 |
| С  |             | SOLVE FOR DISPLACEMENTS AND STRESSES              | FENT0101 |
| Ċ  |             | ******  | FENT0102 |
|    |             | K SW=0  | FENT0103 |
|    |             | CALL STIFF  | FENT0104 |
|    |             | IF (KSW.NE.0) GD TO 900                           | FENT0105 |
| С  |             |   | FENT0106 |
|    |             | CALL BANSCL                                       | FENT0107 |
|    |             | WRITE(6,2052)                                     | FENT0108 |
|    |             |   |          |

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|          |       | WRITE (6.2025) (N.B                     | (2*N-1), B    | (2*N), N=1, NUMNP)      | FENT0109 |   |
|----------|-------|---|---------------|-------------------------|----------|---|
| С        |       |   |               |                         | FENT0110 |   |
|          | 450   | CALL STRESS(SPLOT)                      |               |                         | FENT0111 |   |
| С        | 700   | · 2 *********************************** | ****          | ******                  | FENT0112 |   |
| ĉ        |       | PROCESS ALL DECKS EVEN                  |               |                         | FENT0113 |   |
| C        |       |   | *****         | ****                    | FENT0114 |   |
| ι,       |       | GD TC 910                               |               |                         | FENTO115 |   |
|          | 000   | WRITE (6,4000)                          |               |                         | FENT0116 |   |
|          |       | WRITE (6,4001) HED                      |               |                         | FENT0117 |   |
| С        | ~10   | WRITE 10440011 HED                      |               |                         | FENT0118 |   |
|          | 020   | READ (5,1000) CHK                       |               |                         | FENT0119 |   |
|          | 770   | IF (CHK.NE.STRS) GO TO                  | 920           |                         | FENT0120 |   |
|          |       | Gn T0 50                                | ,20           |                         | FENT0121 |   |
|          | 050   | CONTINUE                                |               |                         | FENT0122 |   |
|          | 750   | WRITE (6,4002)                          |               |                         | FENT0123 |   |
|          |       | CALL EXIT                               |               |                         | FENT0124 |   |
| С        |       |   | ****          | *****                   | FENT0125 | Ş |
| c        |       | ****                                    | ****          | *****                   | FENT0126 | Ì |
| •.•      | 000   | FORMAT (18A4)                           |               |                         | FENT0127 |   |
|          |       | FORMAT (1215)                           |               |                         | FENT0128 |   |
|          |       | FORMAT ( 15.2F10.0)                     |               |                         | FENT0129 |   |
|          |       | FORMAT(2F10.0)                          |               | ,                       | FENT0130 |   |
|          |       | FORMAT (2F10.0)                         |               |                         | FENT0131 |   |
|          |       | FORMAT (3F10.0)                         |               |                         | FENT0132 |   |
|          |       | FORMAT (215.4F10.0)                     |               |                         | FENT0133 |   |
|          |       | FORMAT (615)                            |               |                         | FENT0134 |   |
| C.       | 007   | x · · · · · · · · · · · · · · · · · · · | ****          | *****                   | FENT0135 |   |
|          | 000   | FURMAT (1H1,20A4)                       |               |                         | FENT0136 |   |
| 2        | 006   | FORMAT (28HONUMBER OF I                 | NODAL POINTS  | I3/                     | FENT0137 |   |
| ٤.       |       | 1 28H NUMBER OF ELEMENT                 | S I3)         |                         | FENT0138 |   |
| 2        |       | FORMAT (20HOMATERIAL N                  |               |                         | FENT0139 |   |
| <i>(</i> | 007   | 1 25H INITIAL VERTICAL                  | STRESS= F10.3 | •5X•                    | FENT0140 |   |
|          |       | 2 26HINITIAL HORIZONTAL                 |               |                         | FENT0141 |   |
| 2        | 013   | FORMAT (12H1NODAL POIN                  | T .4X. 4HTYPE | ,4X, 10HR-ORDINATE ,4X, | FENT0142 |   |
| L        |       | 1 10HZ-ORDINATE .10X. 6                 | HR-LOAD ,10X, | 6HZ-LOAD )              | FENT0143 |   |
| 2        |       | FORMAT (112.18.2F14.3.                  |               |                         | FENT0144 |   |
| 4        | ~** * |   |               |                         |          |   |

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| 2015 FORMAT (26HONODAL POINT CARD ERROR N= I5)                          | FENT0145 |
|---|----------|
| 2016 FORMAT (49H1ELEMENT NO. I J K L MATERIAL)                          | FENT0146 |
| 2017 FORMAT (1113,416,1112)   | FENT0147 |
| 2025 FORMAT (12HONODAL POINT ,6X, 14HR-DISPLACEMENT ,6X, 14HZ-DISPLACEM | FENT0148 |
| 1ENT / (I12,1P2D20.7))  | FENT0149 |
| 2041 FORMAT (76HOMODULUS AND YIELD STRESS NORMALIZED WITH RESPECT TO IN | FENT0150 |
| 1ITIAL VERTICAL STRESS )  | FENT0151 |
| 2051 FORMAT(1H0,10X,"E",8X,"NU",/,3X,F11.1,F10.4/)                      | FENT0152 |
| 2052 FORMAT(1H1)  | FENT0153 |
| () ×************************************                                | FENT0154 |
| 3003 FORMAT (1615)  | FENT0155 |
| (   | FENT0156 |
| 4000 FORMAT (//// ' ABNORMAL TERMINATION')                              | FENT0157 |
| 4001 FORMAT (//// ' END OF PROBLEM ' 20A4)                              | FENT0158 |
| 4002 FORMAT (////' END OF JOB')   | FENT0159 |
| C **********************************                                    | FENT0160 |
| 9000 FORMAT(29HOPRESSURE BOUNDARY CONDITIONS/ 24H I J PRESSU            | FENT0161 |
| 1RE )   | FENT0162 |
| 9001 FORMAT(215,F10.0)  | FENT0163 |
| 9002 FORMAT(216,F12.3)  | FENT0164 |
| END   | FENT0165 |
| SUBROUTINE STIFF  | FENT0166 |
| C   | FENT0167 |
| IMPLICIT REAL*8 (A-H,O-Z)   | FENT0168 |
| IMPLICIT INTEGER*2(I-N)   | FENT0169 |
| COMMON STTCP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25),      | FENT0170 |
| 1 DEPTH(25),E(10,25),SIG(7),R(450),Z(450),UR(450),                      | FENT0171 |
| 2 UZ(450),STOTAL(450,4),KSW   | FENT0172 |
| COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NDEPTH,NORM,MTYPE,ICODE(450)         | FENT0173 |
| COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3),                | FENT0174 |
| 1 HH(6.10), RR(4),ZZ(4),C(4,4),H(6,10),D(5,6),F(6,10),TP(6),XI(6),      | FENT0175 |
| 2 EE(10), IX(450,5)   | FENT0176 |
| COMMEN /BANARG/ B(900),A(900,54),MBAND                                  | FENT0177 |
| COMMON/PRFSS/ IBC(200), JBC(200), PR(200), NUMPC                        | FENT0178 |
| DIMENSION CODE(450)   | FENT0179 |
| ()  | FENT0180 |

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FENT0215 FENT0209 FENT0210 FENT0214 FENT0216 FENTO199 FENT0202 FENT0203 FENT0204 FENT0205 FENT0206 FENT0208 FENT0212 FENT0213 FENT0189 FENT0194 FENT0195 FENT0196 FENT0198 FENT0200 FENT0211 FENT0184 FENTO185 **FENT0186** FENT0188 FENT0190 FENT0192 FENT0193 FENTO197 FENT0201 FENT0207 FENT0182 FENT0183 FENT0187 FENT0181 FENT0191 \* ADD FLEMENT STIFFNESS TO TOTAL STIFFNESS IF (IX(N,3)-IX(N,4)) 145,165,145 S(II.JJ)=S(II.JJ)-CC\*S(IO,JJ) (II.JJ)=S(II.JJ)-CC\*S(9.JJ) FORM STIFFNESS MATRIX IF (VOL) 142.142.144 CC=S(I1,10)/S(10,10) CO 150 JJ=1,9 [M(I)=2\*IX(N•I)-2 CC=S(II+9)/S(9+9) WRITE (6.2003) N DO 210 N=1.NUMEL CALL QUAD(N.VGL) INITIALIZATION n0 160 JJ=1.8 00 160 II=1.8 00 150 11=1.9 DO 50 N=1.ND2 DO 166 I=1.4 DO 50 M=1.ND ND2=2\*NUMNP A ( N.M ) =0.0 G0 T0 210 B(N) = 0.0ND=2\*NB KSW=1 NB = 27165 166 06 142 144 145 150 160 50 οc C C С О υu  $\cup \cup \cup$  $\odot$ Ú

| ပ      |     |                              |              |
|--------|-----|------------------------------|--------------|
|        |     | 2 200 I=1.4                  |              |
|        |     | 2 200 K=1.2                  |              |
|        |     |                              | 15           |
|        |     | X+2-I+2=>                    |              |
|        |     | 3 200 J=1.4                  |              |
|        |     | 2 200 L=1.2                  | 1.1          |
|        |     | J=LM(J)+L-TI+1               |              |
|        |     | L=2*J-2+L                    | a -          |
|        |     | F (JJ) 200,200,175           | . <u>.</u> . |
|        | 175 | J) 180.195.195               |              |
|        |     | 3ITF (6,2004) N              |              |
|        |     | SW=1                         | 11           |
|        |     | 0 T0 210                     | 11           |
|        | O.  | ([1],])=A([1,])+S(KK,LL)     | 11           |
|        | 0   | DNTINUE                      | 1.1          |
|        | 210 | DNTINUE                      | 11           |
|        | ŧ.  | F(KSW.EQ.1) GC TC 500        | 11           |
| Ċ      |     |                              | 11           |
| с<br>С |     | ADD CONCENTRATED FORCES      | 11 1         |
| ပ      |     |                              | 1 I          |
|        |     | 250 N=1.NUMNP                | L 1          |
|        |     |                              | 4 1          |
|        |     | )=8(K)+U7(N)                 | 13           |
|        |     | R(K-I)=B(K-I)+UR(N)          | 11           |
|        | 250 | TINUE                        | ŧ1.          |
| ပ      |     |                              | LL. I        |
| C      |     |                              | 1 1          |
| C      |     | PRESSURE BOUNDARY CONDITIONS | 1 I I        |
| C      |     |                              | نا ل         |
|        |     | F (NUMPC) 260.310.260        | _ U          |
|        | 200 | DUC HEIANUMAU<br>Brij        | L.           |
|        |     |                              | LL_          |
|        |     | CODF(I) = ICODE(I)           | ц. :         |
|        |     | CDE())=ICCDE())              | 1            |

FENT0250 FENT0251 FENT0252 FENT0244 FENT0245 FENT0242 FENT0243 FENT0246 FENT0248 FENT0249 FENT0238 FENT0247 FENT0233 FENT0234 FENT0235 FENT0236 FENT0237 FENT0239 FENT0240 ENT0218 ENT0219 ENT0220 =ENT0222 :ENT0223 ENT0224 =ENT0225 FENT0226 FENT0228 FENT0229 FENT0230 FENT0231 FENT0232 FENT0241 =ENT0217 ENT0221 =ENT0227

|             |                                 | NT025    |
|-------------|---------------------------------|----------|
|             | P=PR(L)/6.                      |          |
|             | $((\Gamma) Z - (I) Z)$          |          |
|             | R = (R(J) - R(I)) * P           | NTO25    |
|             | X=2.0*R(I)+R(                   | NTOOR    |
|             | X=R(1)+2.0*R(J                  | NTO 25   |
| 264         |                                 | FENT0259 |
| 0<br>1<br>7 |                                 | ENT026   |
|             |                                 | ENT026   |
|             | TODE(1)) 2                      | ENT026   |
| 170         |                                 | ENT026   |
| -           |                                 | ENT026   |
| 620         | (11-1)=B(11-1)+RX*(COSA*DZ+     | ENT026   |
| -           | (11)=R(11)-RX*(SINA*D7-C0SA*DR) | ENT026   |
| 000         | TNA=0.0                         | ENT026   |
| 2           |                                 | ENT026   |
|             | ELCOREUN 291-2                  | EN TO 26 |
| 100         | INA-DOLOUS - 2010-2010          | ENT027   |
| •           |                                 | ENT027   |
| 696         | (11-1)=8(11-1)+2X*(CDSA*DZ+S    | ENT027   |
| 4           | (') = B(') - Z X*( SINA*DZ-COSA | EN1027   |
| $\sim$      | DNT INITE                       | ENT027   |
|             |                                 | ENT027   |
| -i          | ISDIACEMENT R                   | FNT027   |
|             |                                 | ENT027   |
|             | DO 400 M=1.NUMNP                | ENT027   |
|             | 5                               | ENT027   |
|             |                                 | ENT028   |
|             | JDF(                            | ENT028   |
|             | 1400.370.390.                   | ENTO28   |
| 37.0        | WDDTEY(N-11-ND2)                | ENT028   |
| •           | 400                             | ENT028   |
| 00          | ~                               | ENTO28   |
| 390         | ۲)<br>۲                         | ENT028   |
|             | N=N+1                           | EN1028   |
|             | ALL                             | EN1028   |

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| C FENT2290<br>5 CO RETURN<br>C FENT2291<br>C FENT2291<br>C FENT2292<br>2 CC3 FORMAT (26HONECATIVE AREA ELEMENT NO. 14)<br>7 FENT2292<br>2 CC3 FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE 14)<br>C WARYEXTEXTENT AREA ELEMENT NO. 14)<br>FENT2294<br>FENT2294<br>FENT2297<br>C FNT2297<br>C FNT2297<br>C FENT2297<br>C FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297<br>FENT2297 |   | 400 CONTINUE  | FENT0289 |
|--|---|---|----------|
| C ************************************   |   | C   | FENT0290 |
| 2CC3 FORMAT (26HONEGATIVE AREA ELEMENT ND. I4)       FENT0293         2004 FORMAT (26HOBAND WIDTH EXCEEDS ALLOWABLE I4)       FENT0293         C       ####################################  |   | 500 RETURN  | FENT0291 |
| 20024       FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE 14)       FENT0295         20024       FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE 14)       FENT0295         20124       FENT0295       FENT0295         20124       FENT0297       FENT0297         20124       FENT0297       FENT0297         20124       FENT0297       FENT0297         20124       FENT0297       FENT0297         20124       FENT0291       FENT0291         20124       FENT0291       FENT0291         20124       FENT0291       FENT0302         20124       FENT0301       FENT0303         20124       FENT0302       FENT0303         20124       FENT0311       FENT0302         20144       FENT0312       FENT0312         20144       FENT0314       FENT0314         2014 <td></td> <td>C ************************************</td> <td>FENT0292</td>   |   | C ************************************                                    | FENT0292 |
| C       ####################################   |   | 2003 FORMAT (26HONEGATIVE AREA ELEMENT NO. I4)                            | FENT0293 |
| FND       FENT0296         SUBROUTINE QUAD(N,VOL)       FENT0297         C       FENT0298         IMPLICIT REAL*8 (A-H,O-Z)       FENT0299         IMPLICIT INTEGR*2(1-N)       FENT0300         COMMON       STT0P,HEO(18),SIGIR(25),SIGIZ(25),GAMMA(25),ZKNOT(25),         2       UZ(450),STOTAL(450,4),R(450),Z(450),UR(450),         2       UZ(450),STOTAL(450,4),R(450),Z(450),UR(450),         2       UZ(450),STOTAL(450,4),R(450),P(10),UM(4),D0(3,3),         FENT0303       FENT0303         1       HH(6,10),R(4),ZZ(4),C(4,4),H(6,10),P(10),LM(4),D0(3,3),         2       FE(10),IX(450,5)         COMMON /ARG/ RR(5),ZZZ(5),S(10,10),P(10),LM(4),D0(3,3),       FENT0306         2       FE(10),IX(450,5)         COMMON /ARG/ B(900),A(900,54),MBAND       FENT0306         2       FENT0300         3       FENT0300         4       FENT0300         4       FENT0300         5       FENT0300         4       FENT0300         5       FENT0300         6       FENT0300         6       FENT0300         7       FENT0300         8       FENT0310         9       FENT0311         9 <td></td> <td>2004 FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE I4)</td> <td>FENT0294</td>  |   | 2004 FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE I4)                         | FENT0294 |
| SUBROUTINE QUAD(N,VOL)         FENT0297           C         FENT0298           IMPLICIT REAL*8 (A-H, G-Z)         FENT0299           IMPLICIT INTEGER*2(I-N)         FENT0300           COMMON         STTOP.HED(18),SIGIR(25),SIGIZ(25),GAMMA(25),ZKNOT(25),           IDEPTH(25),E(1C,25),SIG(7),R(450),Z(450),UR(450),         FENT0302           2 UZ(450),STOTAL(450.4),KSW         FENT0303           COMMON /ARG/ RR(5),ZZ(10).10),P(10),UM(4),D0(3,3),         FENT0305           1 HH(6,10),RR(4),ZZ(4),C(4,4),H(6,10),C(6,6),F(6,10),TP(6),XI(6),         FENT0307           COMMON /BANARG/ B(900),A(900,54),MBAND         FENT0308           C ************************************  |   | (   | FENT0295 |
| SUBRDUTINE QUAD(N, VOL)         FENT0297           C         FENT0298           IMPLICIT REAL*8 (A-H, Q-Z)         FENT0299           IMPLICIT INTEGER*2(I-N)         FENT0300           COMMON         STTOP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNDT(25),           IDEPTH(25), E(IC, 25), SIG(7), R(450), Z(450), UR(450),         FENT0302           2         UZ(450), STOTAL(450, 4), KSW         FENT0303           COMMON         ////////////////////////////////////   |   | END   | FENT0296 |
| IMPLICIT REAL*8 (A-H.O-Z)         FENT0299           IMPLICIT INTEGR*8 (I-H.O-Z)         FENT0300           MPLICIT INTEGR*2(I-N)         FENT0301           COMMON SITOP.HED(18).SIGIR(25).SIGIZ(25).GAMMA(25).ZKNOT(25).         FENT0302           2 UZ(450).SITTAL(450.4).KSW         FENT0303           COMMON /INTEGR/ NUMNP.NUMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450)         FENT0304           COMMON /ARG/ RR(5).ZZZ(5).S(10.10).P(10).LM(4).DD(3.3).         FENT0305           1 HH(6.10).RR(4).ZZ(4).C(4.4).H(6.10).C(6.6).F(6.10).TP(6).XI(6).         FENT0306           2 FE(10).TX(450.5)         FENT0303           C MMCN / BANARG/ B(900).A(900.54).MBAND         FENT0308           C MMCN / BANARG/ B(900).A(900.54).MBAND         FENT0311           K=TX(N.3)         FENT0312           L = IX(N.4)         FENT0312           C II = 1         FENT0313           K=TX(N.3)         FENT0314           FENT0315         FENT0316           I = 2         FENT0316           I = 5         FENT0317           I = 6         FENT0316           I = 7         FENT0316           I = 1 (N.4)         FENT0316           I = 1 (N.4)         FENT0316           I = 1 (N.4)         FENT0316           I = 5         FENT0316   |   | SUBROUTINE QUAD(N, VOL)   | FENT0297 |
| IMPLICIT REAL*8 (A-H, O-Z)       FENT0299         IMPLICIT INTEGRX*2(I-N)       FENT0300         COMMON       STOP, HEU(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25),         1 DEPTH(25), E(10, 25), SIG(7), R(450), Z(450), UR(450),       FENT0302         2 UZ(450), STOTAL(450,4), KSW       FENT0305         COMMON       / STOP, HEGR/ NUMMAT, NDEPTH, NORM, MTYPE, ICODE(450)       FENT0305         1 HH(4,10), RR(4), ZZ(4), C(4,4), H(6,10), D(6,6), F(6,10), TP(6), XI(6),       FENT0307         2 FE(10), TX(4), C(4,4), H(6,10), D(6,6), F(6,10), TP(6), XI(6),       FENT0307         C OMMON / BANARG/ B(900), A(900, 54), MBAND       FENT0308         C ************************************   |   |   | FENT0298 |
| COMMON       STTOP.HE0(18).SIGIR(25).SIGIZ(25).GAMMA(25).ZKNOT(25).       FENT0301         1       DEPTH(25).E(10.25).SIG(7).R(450).Z(450).UR(450).       FENT0302         2       UZ(450).STOTAL(450.4).KSW       FENT0303         COMMON       /INTEGR/NUMMP.NUMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450)       FENT0304         COMMON       /INTEGR/NUMMP.NUMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450)       FENT0304         COMMON       /ARG/RR(5).ZZZ(5).S(10,10).P(10).UR(4).OD(3.3).       FENT0305         1       HH(4.10).RR(4).ZZ(4).C(4.4).H(6.10).D(6.6).F(6.10).TP(6).XI(6).       FENT0307         COMMON       /ARG/RR(5).ZZZ(5).S(10,10).P(10).UR(4).OD(3.3).       FENT0307         COMMON       /ARG/RR(5).ZZZ(5).S(10,10).P(10).UR(4).OD(3.3).       FENT0307         COMMON       /ARG/RR(5).ZZZ(5).S(10,10).P(10).UR(4).OD(3.3).       FENT0307         COMMON       /ARG/RR(5).ZZZ(5).S(10,10).P(10).UR(4).OD(3.3).       FENT0307         COMMON       /BANARG/B(900).A(900.54).MBAND       FENT0307         COMMON       /BANARG/B(900).A(900.54).MBAND       FENT0312         I=IX(N.1)       FENT0312       FENT0312         J=IX(N.2)       FENT0313       FENT0314         L=IX(N.3)       FENT0315       FENT0316         I=IX(N.4)       FENT0316       FENT0316         I=IX(N.4)   |   |   | FENT0299 |
| COMMON       STTOP.HED(18).SIGIR(25).SIGI2(25).GAMMA(25).ZKNOT(25).       FENT0301         1       DEPTH(25).E(10.25).SIG(7).R(450).Z(450).UR(450).       FENT0302         2       UZ(450).STTAL(450).SIG(7).R(450).Z(450).UR(450).       FENT0303         2       UZ(450).STTAL(450.S).SIG(7).R(450).Z(450).UR(450).       FENT0303         2       UZ(450).STTAL(450.S).       FENT0303         2       UZ(450).STTAL(450.S).       FENT0304         COMMON /INTEGR/ NUMP.NUMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450)       FENT0305         1       HH(6.10).RR(4).ZZ(4).C(4.4).H(6.10).P(6).F(6.10).TP(6).XI(6).       FENT0306         2       FE(10).TX(450.5)       FENT0307         COMMON /BANARG/ B(900).A(900.54).MBAND       FENT0306         3       I=IX(N.1)       FENT0305         4       FENT0310       FENT0312         5       I=IX(N.2)       FENT0313         6       I=IX(N.4)       FENT0313         6       I=I       FENT0313         7       I=I       FENT0313         8       FENT0314       FENT0314         9       I=I       FENT0315         10       I=I       FENT0316         11       I=IX(N.1)       FENT0316         12=2       FENT0316  |   | IMPLICIT INTEGER*2(I-N)   | FENT0300 |
| 1 DEPTH(25).E(1C.25).SIG(7).R(450).Z(450).UR(450).       FENT0302         2 UZ(450).SIGTAL(450.4).KSW       FENT0303         COMMON /INTEGR/ NUMP.UMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450)       FENT0304         COMMON /ARG/ RRR(5).ZZZ(5).S(10.10).P(10).LM(4).DD(3.3).       FENT0305         1 HH(6.10).RR(4).ZZ(4).C(4.4).H(6.10).C(6.6).F(6.10).TP(6).XI(6).       FENT0306         2 FE(10).IX(450.5)       FENT0306         COMMON /BARAC/ B(900).A(900.54).MBAND       FENT0308         C ####################################   |   |   | FENT0301 |
| COMMON /INTEGR/ NUMNP, NUMEL, NUMMAT, NDEPTH, NORM, MTYPE, ICODE(450)<br>COMMON /ARG/ RR(5), ZZZ(5), S(10,10), P(10), LM(4), DD(3,3),<br>1 HH(5,10), RR(4), ZZ(4), C(4,4), H(5,10), C(6,6), F(6,10), TP(6), XI(6),<br>FENT0306<br>C FE(10), IX(450,5)<br>C OMMON / BANARG/ B(900), A(900,54), MBAND<br>C ************************************  |   |   | FENT0302 |
| COMMON /INTEGR/ NUMNP.NUMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450)       FENT0304         COMMON /ARG/ RRR(5).ZZZ(5).S(10.10).P(10).LM(4).DD(3.3).       FENT0305         1 HH(6.10).RR(4).ZZ(4).C(4,4).H(6.10).C(6,6).F(6.10).TP(6).XI(6).       FENT0307         2 FE(10).TX(450.5)       FENT0305         COMMON /BANARG/ B(900).A(900.54).MBAND       FENT0308         C ************************************   |   | 2 UZ(450).STOTAL(450.4).KSW   | FENT0303 |
| COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3),<br>1 HH(5,10),RR(4),ZZ(4),C(4,4),H(5,10),C(5,6),F(5,10),TP(6),XI(6),<br>2 FE(10),TX(450,5)<br>COMMON /BANARG/ B(900),A(900,54),MBAND<br>FENT0308<br>C ************************************  |   |   | FENT0304 |
| 2       FE(10), TX(450.5)       FENT0307         COMMON /BANARG/ B(900).A(900.54).MBAND       FENT0308         C       ************************************  |   |   | FENT0305 |
| 2       FE(10),IX(450,5)       FENT0307         COMMON /BANARG/ B(900),A(900,54),MBAND       FENT0308         C       ************************************   |   | 1 HH(5,10), RR(4), ZZ(4), C(4,4), H(6,10), D(6,6), F(6,10), TP(6), XI(6), | FENT0306 |
| COMMON / BANARG/ B(900).A(900.54).MBAND       FENT0308         C       ************************************  |   |   | FENT0307 |
| I=IX(N,1)       FENT0310         J=IX(N,2)       FENT0311         K=IX(N,3)       FENT0312         L=IX(N,4)       FENT0313         C       FENT0316         I1=1       FENT0315         I2=2       FENT0316         I3=3       FENT0317         I4=4       FENT0318         I5=5       FENT0318         C       FENT0318         DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP       FENT0321         C       ************************************   |   | COMMON /BANARG/ B(900),A(900,54),MBAND                                    | FENT0308 |
| J=IX(N,2)       FENT0311         K=IX(N,3)       FENT0312         L=IX(N,4)       FENT0313         C       FENT0314         I1=1       FENT0315         I2=2       FENT0316         I3=3       FENT0317         I4=4       FENT0318         I5=5       FENT0319         C       DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP         C       FENT0321         C       FENT0322         C       FENT0323  |   | C xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx                                    | FENT0309 |
| K = I X (N, 3)       FENT0312         L = I X (N, 4)       FENT0313         C       FENT0314         I 1 = 1       FENT0315         I 2 = 2       FENT0316         I 3 = 3       FENT0317         I 4 = 4       FENT0318         I 5 = 5       FENT0319         C       DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP         C       ************************************  |   | $I = I \times (N + 1)$  | FENT0310 |
| L=IX(N.4)<br>C<br>I1=1<br>I2=2<br>I3=3<br>I5=5<br>C<br>DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP<br>C<br>MARKANANANANANANANANANANANANANANANANANANA  |   | J = IX(N,2)   | FENT0311 |
| C       FENT0314         I 1=1       FENT0315         I 2=2       FENT0316         I 3=3       FENT0317         I 4=4       FENT0318         I 5=5       FENT0319         C       DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP       FENT0321         C       C       DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP       FENT0321         C       C       FENT0322       FENT0323         C       C       FENT0323       FENT0323  |   | $K = I \times (N, 3)$   | FENT0312 |
| I1=1       FENT0315         I2=2       FENT0316         I3=3       FENT0317         I4=4       FENT0318         I5=5       FENT0319         C       DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP       FENT0321         C       ************************************   |   | $L = I \times (N, 4)$   | FENT0313 |
| I1=1       FENT0315         I2=2       FENT0316         I3=3       FENT0317         I4=4       FENT0318         I5=5       FENT0319         C       DFTERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP       FENT0321         C       ************************************   |   | C   | FENT0314 |
| I 3=3<br>I 4=4<br>I 5=5<br>C DETERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP<br>C 2888 288 288 288 288 288 288 288 288 2  |   |   | FENT0315 |
| Id=0FENT0318Id=4Id=4Id=5FENT0319Id=5FENT0319CAFFERATRE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIPCAFFERATRE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIPCFENT0322FENT0323CFENT0323   |   | 12 = 2  | FENT0316 |
| I5=5       FENT0319         C       PERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP         C       PERMINE ELASTIC CONSTANTS AND STRESS-STRAIN RELATIONSHIP         C       PENT0321         C       PENT0322         C       PENT0323         C       PENT0323  |   | I3=3  | FENT0317 |
| C       ####################################   |   | 14 = 4  | FENT0318 |
| CDETERMINEELASTICCONSTANTS AND STRESS-STRAIN RELATIONSHIPFENT0321C*********************************  |   | 15=5  | FENT0319 |
| C       ************************************   |   | ······································                                    | FFNT0320 |
| C FENT0323   |   |   |          |
|  |   | C   |          |
| CALL MPROP(N) FENT0324   |   | С   |          |
|  | 1 | CALL MPROP(N)   | FENT0324 |

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FENT0356 FENT0358 FENT0359 FENT0354 FFNT0355 FENT0360 FENT0328 FENT0333 FENT0338 FENT0340 FENT0343 FENT0344 FENT0345 FENT0346 FENT0348 FENT0349 FENT0350 FENT0351 FENT0352 FENT0353 FENT0357 FENT0327 FENT0329 FENT0334 FENT0335 FENT0336 FENT0339 FENT0342 FENT0347 FENT0325 FENT0326 FENT0330 FENT0332 FENT0337 FENT0341 FENT0331 h IF(R(MM).EQ.0..AND.ICDDE(MM).EQ.0) ICDDE(MM)=1 FURM QUADRILATERAL STIFFNESS MATRIX RRR (5)=(RRR(1)+RRR(2)+RRR(3))/3•0 727(5)=(222(1)+222(2)+222(3))/3•0 RRR (5) = (R(I)+R(J)+R(K)+R(L))/4•0 0\*4/(())Z+())+2())+2())/4\*0 IF(XI(1).EC.0.) WRITE(6.2000) N Z Z 2 [F(X1(1).EC.0) WRITE(6.2000) IF(XI(1).E0.0) WRITE(6.2000) IF(XI(1).EQ.0) WRITE(6.2000) CALL TRISTF(I3,I4,I5) CALL TRISTF(I2.13.15) CALL TRISTF(I1.12.13) CALL TRISTF(14,11,15) CALL TRISTF(I1.12.15) IF (K-L) 125,120,125 00 100 JJ=1.10 DO 100 II=1.10 VOL = VOL + XI (1) V0L=V0L+X1(1) VOL = VOL + XT(1) (1) X + X (1)0.0=(11,LL)HH  $0 \cdot 0 = (\Gamma \Gamma \cdot 1 I) S$ 00 95 JJ=1.6 RRR(M) = R(MM)(WW)Z = (W)ZZZ00 94 M=1.4  $MM = I \times (N, M)$ GO TO 160 VOL = XI(1)V0L=0.0 125 40 95 93 100 120 210

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C

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FENT0362 FEN10363 FENT0364 FENT0365 FFNT0366 FENT0368 FENT0369 FENT0370 FENT0374 FENT0375 FENT0376 FENT0378 FEN10379 **FENT0380** FENT0381 FENT0382 FENT0383 FENT0384 FENT0385 FENT0386 FENT0388 FENT0389 FENT0390 FENT0391 FENT0392 FENT0393 FENT0394 FENT0395 FENT0396 FENT0367 FENT0372 FENT0373 FENT0387 FENT0361 FENT0377 FENT0371 STTOP.HED(18).SIGIR(25).SIGIZ(25).GAMMA(25).ZKNOT(25). I HH(6,10), RR(4), ZZ(4), C(4,4), H(6,10), D(6,6), F(6,10), TP(6), XI(6), COMMON / INTEGR / NUMNP,NUMEL,NUMMAT,NDEPTH,NORM,MTYPE,ICODE(450) COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3), 1 DEPTH(25).E(10.25).SIG(7).R(450).Z(450).UR(450). COMMEN / BANARG/ B(900).A(900.54).MBAND ELEMENT . I5) SUBROUTINE TRISTF(II, JJ, KK) 2 UZ (450), ST0TAL (450,4), KSW IMPLICIT REAL\*8 (A-H, C-Z) 0.4/(LL.I)HH=(LL.I)HH IMPLICIT INTEGER#2(I-N) FORMAT (\* ZERD AREA EE(10), IX(450,5) 00 140 JJ=1.10 INITIAL IZATION [1=1, 6]ZZ(3)=ZZZ(KK) RR (3)=RRR (KK) (11) = 777(1)RR (2)=RRR (J) RR ( 4 ) = RRR ( 1 | 27(4)=222(11) RR(1)=RRR(11 LM(2) = JJII = (I)WILM(3)=KK 140 COMMON RETURN \*\*\*\* FND 00 160 140 2000 J C C ပပပ С О

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| ر   |   | ENT039   |
|-----|---|----------|
| נ   | 0 100 1=1.                              | ENT039   |
|     |   | ENT039   |
|     |   | ENT040   |
|     |   | ENT040   |
|     |   | ENT040   |
| •   | · · · · · · · · · · · · · · · · · · ·   | FENT0403 |
|     |   | ENT040   |
| s د | DRW INTEGRAI (G) T*                     | ENT040   |
| ;   |   | ENT040   |
| C   |   | ENT040   |
| )   | (2.6)=X1(1)*(C(1.                       | ENT040   |
|     | (3.5) = XI(1)                           | ENT040   |
|     | (5,5)=D(3,5)                            | ENT041   |
|     | (6.6)=XI(1)*C(2.2                       | ENT041   |
|     | $(1 \cdot 1) = XI(3) * C(3 \cdot 3)$    | ENT041   |
|     | (1.2)=XI(2)*(C(1.                       | ENT041   |
|     | (1,3) = XI(5) * C(3,3)                  | ENT041   |
|     | (1.6) = XI(2) * C(2.3)                  | ENT041   |
|     | (2.2)=XI(1)*(C(1.1)+                    | ENT041   |
|     | (C(1,3)+C(3,3))                         | ENT041   |
|     | (3.3)=XI(6)*C(3.3)+XI(1)                | ENT041   |
|     | (3.6)=XI(4)*C(2.3)                      | ENT041   |
|     |   | ENT042   |
|     |   | ENT042   |
|     | • 1 ) = 0 ( 1 • P)                      | ENT042   |
|     |   | EN1042   |
|     |   | ENT042   |
| ە ر | FURM CUFFFFICIENT-DISPLACEMENT MATRIX   | ENT042   |
| ; د |   | ENT042   |
| 2   | CMM= RR(2)*(77(3)-72(1))+RR(1)*(22(2    | ENT042   |
|     | 0(1.1)=(RR(2)*Z2(3)-RR(3)*Z2(2))/CON    | ENT042   |
|     | D(1,2) = (RR(3) * ZZ(1) - RR(1) * ZZ(3) | ENT042   |
|     | 0(1.3)=(RR(1)*ZZ(2)-KR(2)*ZZ(1))/COM    | ENT043   |
|     | D(2,1) = (77(2) - 27(3)) / COMM         | 040      |
|     | (22(3)-22(1))/CO                        | 043      |
|     |   |          |

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FORM STIFFNESS MATRIX (H) T\*(D)\*(H) FORM STRAIN TRANSFORMATION MATRIX S(I,J)=S(I,J)+H(K,I)\*F(K,J) F(I,J)=F(I,J)+D(I,K)\*H(K,J) DD(3,2) = (RR(1) - RR(3)) / COMMDD(2+3)=(72(1)-22(2))/COMM 0D(3,1)=(RR(3)-RR(2))/COMM 0D(3,3)=(RR(2)-RR(1))/COMM IF (H(K,I)) 138,140,138 (H(K,J)) 128,130,128 410 HH(I.J)=HH(I.J)+H(I.J) H(5,J+1)=DD(2,I) H(6,J+1)=DD(3,1) H(4.J+1)=DD(1.I) H(2, J) = DD(2, I)H(3, J) = DD(3, I)DN 135 J=1.10 H(1, J) = DD(1, I)DD 410 J=1,10 00 140 I=1.10 130 J=1.10 DO 410 I=1.6 140 K=1.6 130 K=1.6 00 129 I=1.6 00 120 I=1.3 J=2\*LM(I)-1 CONTINUE CONTINUE 00 Ļ CO 00 129 138 139 140 128 120 C Ç  $\cup$   $\cup$  $\circ$ C ပပ Q

FENT0466 FENT0459 FENT0462 FENT0465 FENT0467 FENT0468 **FENT0458** FENT0460 FENT0463 FENT0464 FENT0448 FENT0449 **FENT0450** FENT0455 FENT0456 FENT0438 FENT0439 **FENT0443** FENT0444 FENT0445 **FENT0446** FENT0447 FENT0451 FENT0452 FENT0453 FENT0454 FENT0457 FENT0461 FENT0434 FENT0435 FENT0436 FENT0440 FENT0442 FENT0433 FENT0437 FENT0441

FENT0495 **FENT0498** FENT0499 **FENT0500** FENT0503 FENT0504 FENT0494 **FENT0496** FENT0497 **FENT0501** FENT0502 FENT0489 FENT0452 FENT0493 FENT0475 FENT0478 FENT0479 FENT048C FEN10482 **FENT0483** FENT0484 FENT0485 FENT0486 FENT0488 FENT0450 FEN10474 FENT0476 FENT0477 FENT0481 FENT0487 FENT0491 FENT0469 FENT0470 FENT0472 FENT0473 FENT0471 STTDP+HED(18),SIGIR(25),SIGIZ(25),GAMMA(25),ZKNOT(25), HH(6.10),RR(4),ZZ(4),C(4.4),H(6.10),C(6.6),F(6.10),TP(6),XI(6). COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NCEPTH,NORM,MTYPE,ICODE(450) COMMON /ARG/ RRR(5),ZZ(5),S(10,10),P(10),LM(4),DD(3,3), DEPTH(25), E(10,25), SIG(7), R(450), Z(450), UR(450), CUMMEN / BANARG/ 8(900), A(900,54), MBAND CCFF=EE(1)/(1.-EE(2)-2.\*EE(2)\*EE(2)) FORM STRESS STRAIN RELATIONSHIP DETERMINE ELASTIC CONSTANTS UZ (450), STOTAL (450,4), KSW IMPLICIT REAL\*8 (A-H+0-2) FF(1)=EE(1)\*SIGIZ(MTYPE) IMPLICIT INTEGER\*2(I-N) SUBROUTINE MPRCP(N) IF (NORM) 65.75.65 EF(KK) = E(KK, MTYPE)EE(10).IX(450.5) MTYPE=IX(N,5)C(II.JJ) = 0.055 KK=1.2 5 JJ=1.4 5 [[=],4 J = I X (N, 2) $K = I \times (N, 3)$ L = I X (N, 4) $(I \cdot N) \times I =$ CUMMON RETURN 00 FND 00 00 40 55 60 6**5** 500 75 ŝ  $\cup \cup \cup$ C 0000 Q  $\odot$ 

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| ć   | 7     |        |         |       |                       |        |  |                 |              |                  |                      | Ċ             | <b>ت</b>                    |    |         |                      |        |             |               |                              |              |              |                  |                           |              |  |
|---|-------|--------|---------|-------|-----------------------|--------|--|-----------------|--------------|------------------|----------------------|---------------|-----------------------------|----|---------|----------------------|--------|-------------|---------------|------------------------------|--------------|--------------|------------------|---------------------------|--------------|--|
|   |       |        | 250     | 240   |                       | с<br>С | 230  |                 |              |                  |                      |               |                             |    |         |                      |        |             |               |                              |              |              |                  |                           |              |  |
| IMPLICIT REAL*8 (A-H.D-Z)<br>IMPLICIT INTEGER*2(I-N)<br>COMMON STTOP.HED(18).SIGIR(25).SIGIZ(25).GAMMA(25).ZKNOT(25). |       |        | ONTINUE |       | F (ND2-K) 250.240.24C |        | $(\mathbf{x}) = \mathbf{B}(\mathbf{x}) - \mathbf{A}(\mathbf{x} \cdot \mathbf{x}) + \mathbf{U}$ | F (K) 235+235+2 | U ZOU MEZ-MH | MMON / BANARG/ B | LICIT INTEGER*2(I+N) | PIICIT REAL*8 | SUBROUTINE MODIFY (N.U.ND2) | ND | ETURN   | •4)=COEF*(0.5-EE(2)) |        | (3.2) = (1) | (3.1) = (1.1) | $(2 \cdot 3) = C(1 \cdot 1)$ | (2.2) = C(1. | (2.1)=C(1.2) | (1,3) = EE(2) *C | $(1,2) = COEF \neq EE(2)$ | (1,1)=COEF*( |  |
|   |       |        |         |       |                       |        |  |                 |              |                  |                      |               |                             |    |         |                      |        |             |               |                              |              |              |                  |                           |              |  |
| FENT0538<br>FENT0539<br>FENT0540  | ENTOS | FENTO5 | ENTO5   | ENTOS | ENTO52                | ENT052 | ENTOS  | ENT052          | ENTOS2       |                  | ENTOS                | ENT051        | ENTO51                      |    | ENT 051 | ENT051               | ENT051 | ENTO51      | ENTO51        | ENTO51                       | ENTOSO       | ENTOSO       | ENTO 50          | ENTOSO                    | ENTO50       |  |

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|             |                                    | NTOC /   |
|-------------|------------------------------------|----------|
| <b></b>     | L DEPTH(25).E(10.25).SIG(7).R(450) |          |
|             | 2 U7 (450) • STDTAL (450•4) • KSW  | ENT054   |
| •           | GR / NUMNP . NUMEL . NUMMAT . NC   | ENT054   |
|             | L N L W                            | NT054    |
|             |                                    | =NT054   |
|             |                                    | :NT054   |
|             |                                    | =NT054   |
|             | 00 ZOU L-1 0 ZOU L-2 MAANA         | - NT054  |
|             |                                    | ENT054   |
|             |                                    | FENT0550 |
|             |                                    | ENT055   |
|             | IF (ND2.IT.I) GC TC 260            | ENT055   |
|             |                                    | ENT055   |
|             | Ü=ľ.                               | ENT055   |
|             | DD 250 K=L•MBAND                   | ENT055   |
|             |                                    | ENT055   |
| 250         | A(I · J)=A(I · J)-C*A(N · K)       | ENT055   |
| )           | R(I)=B(I)-C*B(N)                   | ENT055   |
| 260         |                                    | ENT055   |
| 280         |                                    | ENT056   |
| )<br>)<br>- |                                    | ENT056   |
|             | RACKSUBSTITUTION                   | ENT056   |
|             |                                    | ENT056   |
|             | N=ND2                              | ENT056   |
| 200         |                                    | ENT056   |
|             |                                    | ENT 056  |
|             | TE (N.I.F.O) 60 TO 500             | ENT056   |
|             | DO 400 K=2. MBAND                  | ENT056   |
|             |                                    | ENT056   |
|             | IE (ND2.11.L) 60 TO 400            | ENT057   |
|             | R(N) = P(N) - A(N, K) + B(L)       | ENTO57   |
| 400         | CONTINUE                           | ENT057   |
| 2           |                                    | ENT057   |
|             | G0 TN 300                          | ENTO57   |
|             |                                    | EN1057   |
| 500         | RETURN                             | ENT057   |

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FENT0585 FENT0594 FENT0596 FENT0598 FENT0605 FENT0606 FEN10607 FENT0608 FENT0609 FENT0610 FENT0578 FENT0579 FENT0586 FENT0587 FENT0588 FENT0589 FENT0593 FENT0595 FENT0599 FENT0600 FENT0602 FFNT0603 FENT0604 FENTO611 FENT0580 FENT0582 FENT0583 FENT0584 **FENT0590** FENT0592 FENT0597 FENT0601 FENT0612 FENT0581 FENT0591 FENT0577 \* SITOP.HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25), I HH(6,10),RR(4),ZZ(4),C(4,4),H(6,10),C(6,6),F(6,10),TP(6),XI(6), COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NCEPTH,NORM,MTYPE,ICODE(450) COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3), DEPTH(25),E(1C,25),SIG(7),R(450),Z(450),UR(450), COMMEN / BANARG/ B(900), A(900,54), MBAND ELEMENT STRESSES AND STRAINS RRR (5)=(R(11)+R(J1)+R(K1)+R(L1))/4•0 Z7Z(5)=(Z(I1)+Z(J1)+Z(K1)+Z(L1))/4•0 RRR (5) = (R ( I1 ) + R ( J1 ) + R (K 1 ) ) / 3•0 722(5)=(2(II)+7(JI)+7(KI))/3**.**0 UZ (450) • STOTAL (450 • 4) • KSW IMPLICIT REAL \*8 (A-H.O-Z) IF (K1-L1.E0.0) G0 T0 50 ELEMENT COORDINATES SUBROUTINE STRESS(SPLOT) IMPLICIT INTEGER\*2(I-N) EE(10),IX(450,5) DD 300 N=1.NUMEL CALL QUAD(N.VOL) COMPUTE STRAINS D0 120 1=1.4 I I = I X (N, I)K 1 = I X (N, 3)L1 = IX(N, 4) $JI = I \times (N, 2)$ G0 T0 100 COMPUTE NOWWOU 1 \*2 = 1 1 FIND END 100 с С  $\circ \circ$ Ċ  $\cup \cup \cup$  $\cup \cup \cup$  $\odot$ 

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|          | 1.1=2*1X{N.1}                           |            | NT061        |
|----------|---|------------|--------------|
|          | p(11-1) = B(JJ-1)                       |            | INT061       |
|          | 20 p[11]=8(.1.1)                        |            | I 901N3      |
|          | )<br>J                                  |            | <b>NT061</b> |
| )        | = 0                                     |            | INT061       |
|          | p(10)=0.0                               |            | ENT061       |
| -        | 30                                      |            | N1061        |
|          |   |            | NT062        |
|          | DD 150 K=1.8                            |            | INT062       |
| <b>-</b> | 150 RR(I)=RR(I)-S(I+8,K)*P(K)           |            | ENT062       |
|          |   |            | EN T 0 6 2   |
|          | CUMM=S(6*6)*S(10*10)-S(6*10)*S(10*6)    |            | ENT062       |
|          | IF (COMM) 155.160.155                   |            | ENT062       |
|          | 55 p(9)=(S(10,10)*RR(1)-S(9,10)*RR(2))/ | COMM       | ENT062       |
|          | p(10)=(-S(10,9)*RR(1)+S(9,9)*RR(2))/    | $\circ$    | EN1062       |
| ပ        |   |            | ENT062       |
|          | 160 DO 170 I=1.6                        |            | ENT062       |
| Ì        | TP(1) = 0.0                             |            | EN 1063      |
|          | DD 170 K=1.10                           |            | ENT063       |
|          | 170 TP([)=TP([)+HH([,K)*P(K)            |            | ENT063       |
| Ċ        | •                                       |            | ENT063       |
| )        | BR(1)=TP(2)                             |            | ENT063       |
|          | RR(2)=TP(6)                             |            | ENT063       |
|          | RR(3)=(TP(1)+TP(2)*RRR(5)+TP(3)*ZZ(     | 5))/RRR(5) | ENT063       |
|          |   |            | ENT063       |
| J        |   |            | ENT063       |
| ပ        | COMPUTE STRESSES                        |            | FENT0639     |
| U<br>U   |   |            |              |
|          |   |            | 1001N-       |
|          | 51611)=0•0<br>00 100 K-1-4              |            | EN1064       |
| -        | POT DO                                  |            | ENT064       |
| -        |   |            | ENT064       |
| ې ر      | COMPUTE PRINCIPLE STRESSES              |            | ENT064       |
| ; د      |   |            | ENT064       |
| 1        | CC=(SIG(1)+SIG(2))/2•C                  |            | INTO         |
|          |   |            |              |

FENT0665 FENT0668 **FENT0683** FENT0649 FENT0650 FENT0652 FENT0653 FENT0654 FENT0655 FENT0656 FENT0657 FENT0658 FENT0659 FENT0660 FENT0662 FENT0663 FENT0664 FENT0666 FENT0667 FENT0669 FENTO670 FENT0672 FENT0673 FENT0674 FENT0675 FENT0676 FENT0678 FENT0679 FENTO680 FENT0681 FENT0682 FENT0684 FENT0651 FENT0661 FENT0671 FENT067 2000 FURMAT (8H1 ELEMENT,8X,'R',8X,'Z',6X,'SIG(R)',6X,'SIG(Z)',5X,'SIG(T 0P1F10.21 WRITE (6,2001) N.RRR(5),ZZZ(5),(SIG(I),I=1,4) IF ((SIG(4),NE.0.),OR.(88.NE.0.)) GD TD 520 CALCULATE RUTATION OF PRINCIPLE PLANES IF(DABS(SIG(4)).LT.1.0E-09) SIG(4)=0.0 (F(DABS(BB).GT.1.0E-09) GO TO 510 DIMENSION XM(7),R(7),Z(7),XX(9) 1P7D12.3. DIMENSION RR(1).Z7(1).XI(1) SIG (7) = (SIG(5) - SIG(6))/2.0 SUBROUTINE INTER(XI, RR, ZZ) ANG=DATAN2 (SIG(4),88)/2.0 IMPLICIT REAL\*8 (A-H.C-Z) CR=DSQRT(BB\*\*2+SIG(3)\*\*2) IMPLICIT INTEGER\*2(I-N) BB=(SIG(1)-SIG(2))/2.0 615 xx(1)=.1259391805448 FORMAT (18,2F9,3, SIG(8)=57.396\*ANG IF(N.NE.1) GO TO 1) • • 4X • • TAU(RZ) • ) OUTPUT STRESSES WRITE (6.2000) S16(5)=CC+CR SIG(6)=CC-CR  $(1) \times (2) = \times (1)$ GO TO 530 CONTINUE ANG=0.0 BB=0.0**RETURN** END 520 530 300 510 615 2001 500  $\cup \cup \cup$ ¢  $\circ \circ \circ$ 

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FENT0715 FENT0719 FENT0696 FENT0699 FENT0700 FENT0709 FENT0713 FENT0714 FENT0716 FENT0717 FENT0718 FENT0720 FENT0685 FENT0686 FENT0688 FENT0689 FENT0690 FENT0692 FENT0693 FENT0694 FENT0695 FENT0698 FENT0702 FENT0703 FENT0704 FENT0705 FENT0706 FENT0708 FENT0710 FENT0687 FENT0701 FENT0707 FENT0691 FENT0697 FENT071 FENT071 ARE A= •5\*(RR(1)\*(ZZ(2)-ZZ(3))+RR(2)\*(ZZ(3)-ZZ(1))+RR(3)\*(ZZ(1)-ZZ(2 XI(6)=XI(6)+Xw(I)\*(Z(I)\*\*2)/(R(I)\*\*2) XI(5)=XI(5)+XM(I)\*Z(I)/(R(I)\*2) R(J)=XX(9)\*RR(I)+(I • - XX(9))\*R(7) Z(I)=XX(8)\*ZZ(I)+(I\*-XX(8))\*Z(7) (2)Z\*((6)XX-\*l)+(I)ZZ\*(6)XX=(f)Z R(I)=XX(8)\*RR(I)+(I\_-XX(8))\*R(7) R(7)=(RR(1)+RR(2)+RR(3))/3. XI(3)=XI(3)+XM(I)/(R(I)\*\*2) Z(7)=(ZZ(1)+ZZ(2)+ZZ(3))/3• X[(†)=X](†)+XW([)\*Z(])/K([) XI(2)=XI(2)+XM(I)/R(I) XX(4)=.1323941527884 XX(8)=.696140478028 XX(9)=.410426152314 (1) WX + (1) IX = (1) IXXI(I) = XI(I) \* AREAXM(I) = XX(I) \* R(I)00 500 I=1.6 DD 200 I=1.7 CO 100 I=1.3 D0 400 I=1.7 DO 300 I=1.6 XX(5)=XX(4) XX[6] = XX[4]XX(3) = XX(1)XX(7)=\*225  $\times I (I) = 0.$ J=[+3 ((()))300 200 400 100 500 C C C C ပ C

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RETURN END

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## APPENDIX C

### FINITE ELEMENT PROGRAM FOR THE ANALYSIS OF ISOTROPIC

ELASTIC AXISYMMETRIC PLATES - THERMAL STRAINS INCLUDED (Ref. 13, 14)

### Program Capabilities:

The following restrictions are placed on the size of problems which can be handled by the program.

| ltem                    | Maximum Number |  |  |
|-------------------------|----------------|--|--|
| Nodal Points            | 450            |  |  |
| Elements                | 450            |  |  |
| Materials               | 25             |  |  |
| Boundary Pressure Cards | 200            |  |  |

Printed output includes:

| 1. | Reprint | of | Input | Data |
|----|---------|----|-------|------|
|----|---------|----|-------|------|

- 2. Nodal Point Displacements
- 3. Stresses at the center of each element.

### Input Data Format:

- A. Identification card (18A4) Columns 1 to 72 of this card contain information to be printed with results.
- B. Control card (515,F10.0)

Columns 1 - 5 Number of nodal points 6 - 10 Number of elements 11 - 15 Number of different materials

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- 16 20 Normalizing stress (see NORM, Appendix B)
  21 25 Number of boundary pressure cards
  26 35 Reference temperature (stress free temperature)
- C. Material Property information

The following group of cards must be supplied for each different material:

First Card - (215, 2F10.0)

| Columns   | 1 - 5     | Materials identification - any number<br>from 1 to 12.                       |
|-----------|-----------|--|
|           | 6 - 10    | Number of different temperatures for which properties are given = 8 maximum. |
|           | 11 - 20   | Initial Z stress.  |
|           | 21 - 30   | Initial R stress.  |
| llowing C | arde - (4 | F(0,0) One card for each temperature   |

Following Cards - (4F10.0) One card for each temperature

Columns 1 - 10 Temperature

11 - 20 Modulus of elasticity - E

- 21 30 Poisson's ratio v
- 31 40 Coefficient of thermal expansion

D. Nodal Point Cards - (215, 5F10.0)

One card for each nodal point with the following information:

Columns 1 - 5 Nodal point number 10 Number which indicates if displacements or forces are to be specified. 11 - 20 R - ordinate 21 - 30 Z - ordinate 31 - 40 XR 41 - 50 · XZ 51 - 60 Temperature If the number in column 10 is

| 0  | XR is the specified R-load and<br>XZ is the specified Z - load              | free  |
|----|---|-------|
| 1  | XR is the specified R-displacement and XZ is the specified Z-load.          | Ø     |
| 2. | XR is the specified R-load and XZ is the specified Z-displacement.          |       |
| 3  | XR is the specified R-displacement and XZ is the specified Z- displacement. | fixed |

All loads are considered to be total forces acting on a one radian segment. Nodal point cards must be in numerical sequence. If cards are omitted, the omitted nodal points are generated at equal intervals along a straight line between the defined nodal points. The necessary temperatures are determined by linear interpolation. The boundary code (column 10), XR and XZ are set equal to zero.

Skew Boundaries:

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If the number in columns 5-10 of the nodal point cards is other than 0, 1, 2 or 3, it is interpreted as the magnitude of an angle in degrees. The terms in columns 31-50 of the nodal point card are then interpreted as follows:

XR is the specified load in the s-direction

XZ is the specified displacement in the n-direction The angle must always be input as a negative angle and may range from -.001 to -180 degrees. Hence, +1.0 degree is the same as -179.0 degrees. The displacements of these nodal points which are printed by the program are

Condition

 $u_r$  = the displacement in the s-direction  $u_z$  = the displacement in the n-direction

E. Element Cards - (615)

One card for each element

| Columns | 1 - 5   | Element number               | 1. | Order nodal points                        |
|---------|---------|------------------------------|----|---|
|         | 6 - 10  | Nodal Point I                |    | counter-clockwise<br>around element.      |
|         | 11 - 15 | Nodal Point J                |    |   |
|         | 16 - 20 | Nodal Point K                | 2. | Maximum difference<br>between nodal point |
|         | 21 - 25 | Nodal Point L                |    | I.D. must be less                         |
|         | 26 - 30 | Material Identi-<br>fication |    | than 25.                                  |

Element cards must be in element number sequence. If element cards are omitted, the program automatically generates the omitted information by incrementing by one the preceding I, J, K and L. The material identification code for the generated cards is set equal to the value given on the last card. The last element card must always be supplied.

Triangular elements are also permissible; they are identified by repeating the last nodal point number (i.e., I, J, K, K).

F. Pressure Cards - (215, 1F10.0) One card for each boundary element which is subjected to a normal pressure.

> Columns 1 - 5 Nodal Point I 6 - 10 Nodal Point J 11 - 20 Normal Pressure

The boundary element must be on the left as one progresses from I to J. Surface tensile force is input as a negative pressure. Listing:

|    | TTO STUD.  |          |
|----|--|----------|
| С  | ********   | FEWT0001 |
| C  | FINITE ELEMENT PROGRAM FOR THE ANALYSIS OF ISOTROPIC ELASTIC       | FEWT0002 |
| C. | AXYSYMMETRIC PLATES REF FEAST 1,3 SAAS 2                           | FEWT0003 |
| С  | ***************************************                            | FEWT0004 |
| C  |  | FEWT0005 |
|    | IMPLICIT REAL*8 (A-H,O-Z)  | FEWT0006 |
|    | IMPLICIT INTEGER*2(I-N)  | FEWT0007 |
|    | COMMON STTOP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25), | FEWT0008 |
|    | 1DEPTH(25), E(8,4,25), SIG(7), R(450), Z(450), UR(450), TT(3),     | FEWT0009 |
|    | 2 U7(450), STOTAL(450,4),  | FEWT0010 |
|    | 3 T(450).TEMP,Q.KSW  | FEWT0011 |
|    | COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NDEPTH,NORM,MTYPE,ICODE(450)    | FEWT0012 |
|    | COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3),           | FEWT0013 |
|    | 1 HH(6,10),RR(4),ZZ(4),C(4,4),H(6,10),D(6,6),F(6,10),TP(6),XI(6),  | FEWT0014 |
|    | 2 EE(10), [X(450,5)  | FEWT0015 |
|    | COMMUN /BANARG/ B(900),A(900,54),MBAND                             | FEWT0016 |
|    | COMMON/PRESS/ IBC(200), JBC(200), PR(200), NUMPC                   | FEWT0017 |
|    | DATA STRS / *****/   | FEWT0018 |
| С  | *************************  | FEWT0019 |
| С  | READ AND PRINT CONTROL INFORMATION                                 | FEWT002C |
| С  | ***********************  | FEWT0021 |
|    | 50 READ (5,1000,END=950) HED                                       | FEWT0022 |
|    | WRITE (6,2000) HED   | FEWT0023 |
| С  |  | FEWT0024 |
|    | READ(5.1001) NUMNP.NUMEL.NUMMAT,NORM.NUMPC.Q                       | FEWT0025 |
|    | WRITE(6,2006) NUMNP,NUMEL,NUMMAT,NUMPC,Q                           | FEWT0026 |
|    | IF (NORM) 65,65,66   | FEWT0027 |
|    | 66 WRITE (6,2041)  | FEWT0028 |
| С  | **********************   | FEWT0029 |
| С  | READ AND PRINT MATERIAL PROPERTIES                                 | FEWT0030 |
| С  | **********************   | FEWT0031 |
|    | 65 CONTINUE  | FEWT0032 |
| С  |  | FEWT0033 |
|    | DO 80 M=1.NUMMAT   | FEWT0034 |
|    | READ(5,1012) MTYPE, NUMTC, SIGIZ(MTYPE), SIGIR(MTYPE)              | FEWT0035 |
|    | WRITE(6,2011)MTYPE,NUMTC,SIGIZ(MTYPE),SIGIR(MTYPE)                 | FEWT0036 |
|    |  |          |

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000 0 0 0 13 112 د.... ب.... 110 106 ្រុះ 100 20 80 81 WRITE (6.2015) N WRITE(6,2014) (K, ICODE(K), R(K), Z(K), UR(K), UZ(K), T(K), K=NL, N) WRITE (6,2016) NL=L+1 WRITE (6,2013) CONTINUE N=0 READ AND PRINT ELEMENT PROPERTIES G0 T0 900 UZ(L) = 0.0UR(L) = 0.0READ(5,1006) N.ICODE(N), R(N), Z(N), UR(N), UZ(N), T(N) READ AND PRINT NODAL POINT DATA E(I.J.MTYPE) = E(NUMTC.J.MTYPE DO 81 I=NUMTC.8 WRITE(6.2010) ((E(I.J.MTYPE),J=1.4).I=1.NUMTC1 R(L) = R(L-1) + DRL=L+1 DT = (T(N) - T(L)) / ZXDZ = (Z(N) - Z(L))/ZXDR = (R(N) - R(L)) / ZXD0 81 J=1,4 READ(5.1011) ((E(I.J.MTYPE),J=1.4),I=1.NUMTC) IF (NUMNP-N) 113.120.105 GO TO 110 T(L) = T(L-1) + DTZ X = N - LZ(L) = Z(L-1) + DZ $I C \cap D \in (L) = 0$ IF (N-L) 113.112.111 IF (L.EQ.0) 60 TO 110 FEWT0051 FEWT0048 FEWT0046 FEWT0043 FEWT0042 FEWT004 FEWT0040 FEWT0039 FEWT0038 FEWT0066 FEWT0062 FEWT0057 FEWT0054 FEWT0053 FEWT0052 FEWT0050 FEWT0049 FEWT0045 FEWT007C FENT0069 FEWT0068 FEWT0067 FEWT0065 FEWT0064 FEWT0063 FEWT0061 FEWT0060 FEWT0059 FEWT0058 FEWT0056 FEWT0055 FEWT0047 FEWT0072 FEWT0071 EWT0044 EWT0037

|   | 130 | READ (5,1007) M,(IX(M,I),I=1,5)                       | FEWT0073 |
|---|-----|---|----------|
|   | 140 | N=N+1   | FEWT0074 |
|   |     | IF (M-N) 170,170,150                                  | FEWT0075 |
|   | 150 | $I \times (N, 1) = I \times (N-1, 1) + 1$             | FEWT0076 |
|   |     | IX(N,2) = IX(N-1,2) + 1                               | FEWT0077 |
|   |     | IX(N,3)=IX(N-1,3)+1                                   | FEWT0078 |
|   |     | $I \times (N \cdot 4) = I \times (N - 1 \cdot 4) + 1$ | FEWT0079 |
|   |     | IX(N,5) = IX(N-1,5)                                   | FEWT0080 |
|   | 170 | WRITE (6,2017) N.(IX(N,I),I=1.5)                      | FEWT0081 |
|   |     | IF (M-N) 180,180,140                                  | FEWT0082 |
|   | 180 | IF (NUMEL-N) 300,300,130                              | FEWT0083 |
| С |     | ***************************************               | FEWT0084 |
| С |     | READ AND PRINT THE PRESSURE CARDS                     | FEWT0085 |
| С |     | ******************                                    | FEWTC086 |
|   | 300 | IF(NUMPC) 290,210,290                                 | FEWTOC87 |
|   | 290 | WRITE(6,9000)   | FEWT0088 |
|   |     | DO 200 L=1.NUMPC                                      | FEWT0089 |
|   |     | READ(5,9001) IBC(L),JBC(L),PR(L)                      | FEWT0090 |
|   | 200 | WRITE(6,9002) IBC(L), JBC(L), PR(L)                   | FEWT0091 |
|   | 210 | CONTINUE  | FEWT0092 |
| С |     | *******************************                       | FEWT0093 |
| С |     | DETERMINE BAND WIDTH                                  | FEWT0094 |
| С |     | *******************************                       | FEWT0095 |
|   |     | J=0   | FEWT0096 |
|   |     | DO 340 N=1.NUMEL                                      | FEWTOC97 |
|   |     | DO 340 I=1+4  | FEWT0098 |
|   |     | DD 325 L=1.4  | FEWTC099 |
|   |     | $KK = I \times (N \cdot I) - I \times (N \cdot L)$    | FEWT0100 |
|   |     | IF (KK.LT.O) KK=-KK                                   | FEWT0101 |
|   |     | IF (KK.GT.J) J=KK                                     | FEWT0102 |
|   | 325 | CONTINUE  | FEWT0103 |
|   | 340 | CONTINUE  | FEWT0104 |
|   |     | MBAND=2*J+2   | FEWT0105 |
| C |     | ***************************************               | FEWT0106 |
| C |     | SULVE FOR DISPLACEMENTS AND STRESSES                  | FEWT0107 |
| C |     | ***************************************               | FEWT0108 |

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|      | KSW=0  | FEWT0109 |
|------|--|----------|
|      | CALL STIFF                                     | FEWT0110 |
|      | IF (KSW.NE.0) GO TO 900                        | FEWT0111 |
| C    |  | FEWT0112 |
|      | CALL BANSOL                                    | FEWT0113 |
|      | WRITE(6,2052)                                  | FEWT0114 |
|      | WRITE (6,2025) (N,B (2*N-1),B (2*N),N=1,NUMNP) | FEWT0115 |
| С    |  | FEWT0116 |
|      | CALL STRESS(SPLOT)                             | FEWT0117 |
| С    | ***************************************        | FEWT0118 |
| С    | PROCESS ALL DECKS EVEN IF ERROR                | FEWT0119 |
| С    | **********************                         | FEWT0120 |
|      | GO TO 910                                      | FEWT0121 |
| 900  | WRITE (6,4000)                                 | FEWT0122 |
| 910  | WRITE (6,4001) HED                             | FEWT0123 |
| С    |  | FEWT0124 |
| 920  | READ (5,1000) CHK                              | FEWT0125 |
|      | IF (CHK.NE.STRS) GO TO 920                     | FEWT0126 |
|      | GO TO 50                                       | FEWT0127 |
| 950  | CONTINUE                                       | FEWT0128 |
|      | WRITE (6,4002)                                 | FEWT0129 |
|      | CALL EXIT                                      | FEWT0130 |
| C    | ********                                       | FEWT0131 |
| С    | **************************************         | FEWT0132 |
| 1000 | FORMAT (18A4)                                  | FEWT0133 |
| 1001 | FORMAT(515,F10.0)                              | FEWT0134 |
| 1002 | FORMAT ( 15,2F10.0)                            | FEWT0135 |
|      | FORMAT(2F10.0)                                 | FEWT0136 |
| 1004 | FORMAT (2F10.0)                                | FEWT0137 |
| 1005 | FORMAT (3F10.0)                                | FEWT0138 |
| 1006 | FORMAT(215.5F1C.0)                             | FEWT0139 |
| 1007 | FORMAT (615)                                   | FEWT0140 |
| 1011 | FORMAT(4F10.0)                                 | FEWT0141 |
| 1012 | FURMAT(215.2F1C.C)                             | FEWT0142 |
| С    | ***************************************        | FEWT0143 |
| 2000 | FURMAT (1H1,20A4)                              | FEWT0144 |

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| 2006 FORMAT (//+  | FEWT0145 |
|---|----------|
| 1 30HO NUMBER OF NODAL POINTS I3 /                                      | FEWT0146 |
| 2 30HO NUMBER OF ELEMENTS I3 /  | FEWT0147 |
| 3 30HO NUMBER OF DIFF. MATERIALS I3 /                                   | FEWT0148 |
| 4 30HO NUMBER DF PRESSURE CARDS I3 /                                    | FEWT0149 |
| 5 30HO REFERENCE TEMPERATURE E12.4)                                     | FEWT0150 |
| 2010 FORMAT (15HO TEMPERATURE 15X 5HE 15X 6HNU 15X 6HALPHA 9X           | FEWT0151 |
| 1/4F20.8)   | FEWT0152 |
| 2011 FORMAT (17HOMATERIAL NUMBER= 13, 30H, NUMBER OF TEMPERATURE CARDS= | FEWT0153 |
| 1 13,25H INITIAL VERTICAL STRESS= F10.3,5X,                             | FEWT0154 |
| 2 27H INITIAL HORIZONTAL STRESS= F10.3)                                 | FEWT0155 |
| 2013 FORMAT (12H1NODAL POINT ,4X, 4HTYPE ,4X, 10HR-ORDINATE ,4X,        | FEWT0156 |
| 1 10HZ-ORDINATE ,10X,6HR-LOAD ,10X, 6HZ-LOAD,10X,4HTEMP )               | FEWT0157 |
| 2014 FORMAT(112,18,2F14.3,2E16.5,F14.3)                                 | FEWT0158 |
| 2015 FORMAT (26HONDDAL POINT CARD ERROR N= I5)                          | FEWT0159 |
| 2016 FORMAT (49HIELEMENT NO. I J K L MATERIAL )                         | FEWT0160 |
| 2017 FORMAT (1113,416,1112)   | FEWT0161 |
| 2025 FORMAT (12HONODAL POINT .6X, 14HR-DISPLACEMENT .6X, 14HZ-DISPLACEM | FEWT0162 |
| 1ENT / (112,1P2D20.7))  | FEWT0163 |
| 2041 FORMAT (76HOMODULUS AND YIELD STRESS NORMALIZED WITH RESPECT TO IN | FEWT0164 |
| LITIAL VERTICAL STRESS )  | FEWT0165 |
| 2051 FORMAT(1H0,10X,"E",8X,"NU",/,3X,F11.1,F10.4/)                      | FEWT0166 |
| 2052 FORMAT(1H1)  | FEWT0167 |
| C ************************************                                  | FEWT0168 |
| 3003 FORMAT (1615)  | FEWT0169 |
| C ************************************                                  | FEWT0170 |
| 4000 FORMAT (//// * ABNORMAL TERMINATION*)                              | FEWT0171 |
| 4001 FORMAT (//// ' END OF PROBLEM ' 20A4)                              | FEWT0172 |
| 4002 FORMAT (////' END OF JOB')   | FEWT0173 |
| C   | FEWT0174 |
| 9000 FORMAT(29HOPRESSURE BOUNDARY CONDITIONS/ 24H I J PRESSU            | FEWT0175 |
| 1RE )   | FEWT0176 |
| 9001 FORMAT(215,F10.0)  | FEWT0177 |
| 9002 FORMAT(216,F12.3)  | FEWT0178 |
| END   | FEWT0179 |
| SUBROUTINE STIFF  | FEWT0180 |

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| ~ |  | FEWT0181 |
|---|--|----------|
| С |  | FEWT0182 |
|   | IMPLICIT REAL*8 (A-H, C-Z)   | FEWT0182 |
|   | IMPLICIT INTEGER*2(I-N)<br>COMMON STTOP,HED(18),SIGIR(25),SIGIZ(25),GAMMA(25),ZKNGT(25), | FEWT0184 |
|   |  | FEWT0185 |
|   | 1DEPTH(25), E(8,4,25), SIG(7), R(450), Z(450), UR(450), TT(3),                           | FEWT0186 |
|   | 2 UZ(450), STOTAL(450,4),  | FEWT0187 |
|   | 3 T(450), TEMP, Q, KSW   | FEWT0188 |
|   | COMMON /INTEGR/ NUMNP, NUMEL, NUMMAT, NDEPTH, NORM, MTYPE, ICODE(450)                    | FEWT0189 |
|   | COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3),                                 |          |
|   | 1 HH(6,10), RR(4), ZZ(4), C(4,4), H(6,10), D(6,6), F(6,10), TP(6), XI(6),                | FEWT0190 |
|   | 2 EE(10).IX(450.5)   | FEWT0191 |
|   | COMMON / BANARG/ B(900), A(900, 54), MBAND   | FEWT0192 |
|   | COMMON/PRESS/ IBC(200), JBC(200), PR(200), NUMPC   | FEWT0193 |
|   | DIMENSION CODE(450)  | FEWT0194 |
| С | *******  | FEWT0195 |
| C | INITIALIZATION   | FEWT0196 |
| C | ***************************************  | FEWT0197 |
|   | NB=27  | FEWT0198 |
|   | ND=2*NB  | FEWT0199 |
|   | ND2=2*NUMNP  | FEWT0200 |
|   | DO 50 N=1.ND2  | FEWT0201 |
|   | B(N) = 0.0   | FEWT0202 |
|   | DO 50 M=1+ND   | FEWT0203 |
|   | 50 A(N+M)=0+0  | FEWT0204 |
| С | *******************  | FEWT0205 |
| С | FORM STIFFNESS MATRIX  | FEWT0206 |
| C | **************************************   | FEWT0207 |
|   | DO 210 N=1.NUMEL   | FEWT0208 |
| С |  | FEWT0209 |
| С |  | FEWT0210 |
|   | 90 CALL QUAD(N,VOL)  | FEWT0211 |
|   | IF (VOL) 142.142.144   | FEWT0212 |
|   | 142 WRITE (6,2003) N   | FEWT0213 |
|   | K S W = 1  | FEWT0214 |
|   | GO TO 210  | FEWT0215 |
| С |  | FEWT0216 |
|   |  |          |

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| 145 D0 150 TT=1.9<br>150 D1 50 TT=1.9<br>150 D1 50 J1=1.8<br>150 D1 60 TT=1.8<br>150 D1 60 TT=1.8<br>150 D1 60 TT=1.8<br>150 D1 60 TT=1.8<br>150 D1 10 =0110-CC*5(10.JJ)<br>150 D1 10 =0110-CC*70(9)<br>150 D1 10 =01020<br>160 D1 10 =01020<br>170 C001100<br>170 C00100<br>170 C001000<br>170 C001000<br>170 C00000<br>170 C000000<br>170 C000000<br>170 C00000000<br>1   | 144      | 1F (IX(N                               | EWT021         |
|--|----------|--|----------------|
| p(11)=p(11)-CC*p(10)       p(11)=p(11)-CC*p(10)         p(11)=p(11)-CC*s(10.JJ)       p(11)=p(11)-CC*s(10.JJ)         p(11)=p(11)-CC*s(10.JJ)       p(11)=p(11)-CC*s(10.JJ)         p(11)=p(11)-CC*p(9)       p(11)=p(11)-CC*s(10.JJ)         p(11)=p(11)-CC*s(10.JJ)       p(11)=p(11)-CC*s(10.JJ)         p(11)=p(11)-CC*s(10.JJ)       p(11)=p(11)-CC*s(10.JJ)         p(11)=p(11)-p(11)-CC*s(10.JJ)       p(11)=p(11)-CC*s(10.JJ)         p(11)=p(11)-D(11)       p(11)-D(11)         p(11)=p(11)-D(11)       p(11)-D(11)         p(11)=p(11)-D(11)       p(11)-D(11)         p(11)=2*1(N,1)-2       p(11)-D(11)         p(11)=2*1(N,1)-2       p(11)-2         p(11)=2*1(N,1)-2       p(11)-2         p(11)=2*1(N,1)-2       p(11)-2         p(11)=2*1(N,1)-2       p(11)-2         p(11)=2*1(N,1)-2       p(11)-2         p(11)=2*1(N,1)-2       p(11)-2         p(11)=2*1(N,1)-1       p(11)-2         p(11)=2*1(N,1)-1       p(11)-2         p(11)=2*1(N,1)-1       p(11)-2         p(11)=2*1(N,1)-1       p(11)-2         p(2)=200       p(2)=2         p(2)=200       p(2)=2         p(2)=200       p(2)=2         p(2)=200       p(2)=2         p(2)=2       p(2  | 45       | 00 150 T                               | EWT02<br>EWT02 |
| DD 155 JJ=1.5<br>DD 155 JJ=1.5<br>DD 165 JJ=1.5<br>CC=S(I1.JJ)=S(I1.JJ)-CC*S(10.JJ)<br>FEWT02<br>CC=S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>DD 16C JJ=1.8<br>S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>DD 16C JJ=1.8<br>S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>DD 16C JJ=1.8<br>DD 16C JJ=1.8<br>S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>S(I1.JJ)=S(I1.JJ)-CC*S(9.JJ)<br>DD 16C JJ=1.8<br>DD 16C JJ=1.8<br>EWT02<br>DD 16C JJ=1.8<br>EWT02<br>DD 200 I=1.4<br>EWT02<br>DC 200 I=1.4<br>EWT02<br>DC 200 I=1.4<br>EWT02<br>DC 200 I=1.4<br>EWT02<br>DC 200 I=1.4<br>EWT02<br>DC 200 I=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>EWT02<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>EWT02<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>EWT02<br>DD 200 L=1.2<br>J=W11J+LI11<br>I1=2*J-2*L<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02<br>EWT02  |          | b(II)=b(II)-CC*b(IC)                   | EWT022         |
| <pre>0 \$(II.JJ)=\$(II.JJ)-CC*\$(10.JJ)<br/>D0 160 II=1.8<br/>CC=\$(II.9)/\$(9.9)<br/>P(II1)=P(II1-CC**(9.JJ)<br/>D0 166 J=1.4<br/>ADD ELEMENT \$TIFFNESS TO TOTAL \$TIFFNESS<br/>FEWT02<br/>FEWT02<br/>D0 166 I=1.4<br/>b LM(J)=2*IX(N.1)-2<br/>D0 200 T=1.4<br/>b LM(J)=2*IX(N.1)-2<br/>D0 200 T=1.4<br/>b LM(J)=2*IX(N.1)-2<br/>D0 200 T=1.4<br/>f LM(J)=2*IX(N.1)-2<br/>D0 200 T=1.4<br/>f LM(J)=2*IX(N.1)-2<br/>D0 200 T=1.4<br/>f LM(J)=2*IX(N.1)-2<br/>f LM(J)=2*IX(N.1)-2<br/>f LM(J)=2*IX(N.1)-2<br/>D0 200 T=1.4<br/>f LM(J)=2*IX(N.1)-2<br/>f LM(J)=2*IX(N</pre>  |          | D0 150 JJ=1.9                          | EWT022         |
| D0 160 11=1.8<br>CC=S(11.9)/S(9.9)<br>FUTU2<br>CC=S(11.9)/S(9.1)<br>D0 16C JJ=1.8<br>D0 16C JJ=1.8<br>D0 16C JJ=1.8<br>D0 16C JJ=1.8<br>ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS<br>ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS<br>FEWT02<br>FEWT02<br>D0 200 T=1.4<br>D0 200 T=1.4<br>D0 200 T=1.4<br>D0 200 T=1.4<br>D0 200 T=1.4<br>D0 200 T=1.4<br>D0 200 T=1.4<br>D1 200 L=1.2<br>JJ=LM(J)+L<br>T(J) 200 L=1.2<br>JJ=LM(J)+L<br>T(J) 200 L=1.2<br>JJ=LM(J)+L<br>T(J) 200 L=1.2<br>D0 200 L=1.2<br>JJ=LM(J)+L<br>T(J) 200 L=1.2<br>D1 200 L=1.2<br>D1 200 L=1.2<br>D1 200 L=1.2<br>D1 200 L=1.4<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT   | .50      | <pre>S(II., JJ)=S(II., JJ)-CC*</pre>   | EWT022         |
| D0 160 11=1.8<br>CCCST(11:91)5(9:9)<br>P(11)=P(11)-CC*P(9)<br>D0 16C JJ=1.8<br>D0 16C JJ=1.8<br>D0 16C JJ=1.8<br>D0 16C JJ=1.8<br>D0 ELEMENT STIFFNESS TO TOTAL STIFFNESS<br>ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS<br>FEWT02<br>DD 200 1=1.4<br>DD 200 1=1.4<br>DD 200 1=1.4<br>DD 200 1=1.4<br>DD 200 1=1.4<br>DD 200 1=1.4<br>DD 200 1=1.2<br>DD 200 1=1.4<br>DD 200 1=1.2<br>DD 200 1=1.4<br>DD 200 1=1.2<br>DD 200 1=1.4<br>DD 200 1=1.2<br>DD 200 1=1.2<br>DD 200 1=1.4<br>DD 200 1=1.2<br>DD 200 100 12<br>DD 200 10 12<br>DD 200 12<br>DD 200 10 12<br>DD 200   |          |  | EWT022         |
| CC=S(II:9)/S(9:9)       FEWT02         P(II:) = P(II) - CC*F(9)       FEWT02         D0 160 Jb=.8       FEWT02         ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS       FEWT02         BOD 200 1=1.4       FEWT02         BOD 200 1=1.4       FEWT02         BOD 200 1=1.4       FEWT02         BOD 200 1=1.4       FEWT02         BOD 200 1=1.2       FEWT02         BOD 200 1=1.4       FEWT02     <  |          | DO 160 II=1.8                          | EWT022         |
| P(III)=P(II)-CC*P(9)       FEWT02         D01 160 JJ=1.8       FEWT02         S(II:JJ)=S(II.JJ)-CC*S(9.JJ)       FEWT02         ADD ELEMFNT STIFFNESS TO TOTAL STIFFNESS       FEWT02         ADD ELEMFNT STIFFNESS TO TOTAL STIFFNESS       FEWT02         ADD 166 1=1.4       FEWT02         BD 166 1=1.4       FEWT02         BD 106 1=1.4       FEWT02         BD 200 1=1.4       FEWT02         DD 200 1=1.2       FEWT02   |          | CC=S(II,9)/S(9,9)                      | EWT022         |
| DG 16C JJ=1.8<br>DG 16C JJ=1.8<br>ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS<br>FEWT02<br>FEWT02<br>DG 166 i=1.4<br>FEWT02<br>EMT02<br>DG 200 i=1.4<br>DG 200 i=1.4<br>EMT02<br>DG 200 i=1.4<br>DG 200 i=1.4<br>DG 200 i=1.4<br>DG 200 i=1.4<br>DG 200 i=1.4<br>DG 200 j=1.4<br>DG 200 j=1.4<br>EMT02<br>DG 200 j=1.4<br>EMT02<br>EMT02<br>CONTINUE<br>EMT02<br>EMT02<br>EMT02<br>DG 200 j=1.4<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>EMT02<br>E   |          | b(II)=b(II)-CC*b(6)                    | EWT022         |
| 0 S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(IIJJ)=S(II.JJ)=S(IJ)   |          | D0 160 JJ=1.8                          | EWT022         |
| ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS       FEWT02         FEWT02       FEWT02         LM(I)=2*IX(N,I)-2       FEWT02         LM(I)=2*IX(N,I)-2       FEWT02         LM(I)=2*IX(N,I)-2       FEWT02         LM(I)=2*IX(N,I)-2       FEWT02         DO 200 I=1,4       FEWT02         DO 200 I=1,4       FEWT02         DO 200 F=1,2       FEWT02         III=LM(I)+K       FEWT02         DO 200 J=1,4       FEWT02         DO 200 J=1,4       FEWT02         DO 200 J=1,4       FEWT02         DI 200 L=1,2       FEWT02         DI 210       FEWT02 <td>60</td> <td>S(II, JJ)=S(II, JJ)-CC*</td> <td>EWT022</td>  | 60       | S(II, JJ)=S(II, JJ)-CC*                | EWT022         |
| ADD ELEMENT STIFFNESS TO TOTAL STIFFNESS       FEWT02         5 DN 166 F=1.4       FEWT02         6 LM(1)=2*IX(N.T)-2       FEWT02         6 LM(1)=2*IX(N.T)-2       FEWT02         7 DN 166 F=1.4       FEWT02         7 DN 166 F=1.4       FEWT02         7 DN 166 F=1.4       FEWT02         7 DN 200 F=1.4       FEWT02         7 DN 200 F=1.2       FEWT02         7 DN 200 J=1.4       FEWT02         7 DN 200 L=1.2       FEWT02  |          |  | EWT022         |
| <pre>5 DU 166 I=1.4<br/>6 LM(I)=2*IX(N.I)-2<br/>6 EWT02<br/>DO 200 I=1.4<br/>DO 200 K=1.2<br/>IT=LM(I)+K<br/>EWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>DO 200 I=1.4<br/>DO 200 L=1.2<br/>JJ=LM(J)+L-II+J<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2+L<br/>II=2*J-2</pre>   |          | DD ELEMENT STIFFNESS TO TOTAL STIFFNES | EWT023         |
| <pre>5 DD 166 I=1.4<br/>6 LM(I)=2*IX(N.I)-2<br/>7 FEWT02<br/>DD 200 I=1.4<br/>DD 200 I=1.4<br/>DD 200 I=1.4<br/>DD 200 I=1.2<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>DD 200 J=1.4<br/>DD 200 J=1.4<br/>DD 200 J=1.4<br/>DD 200 J=1.4<br/>DD 200 J=1.4<br/>DD 200 J=1.4<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT02<br/>FEWT0</pre> |          |  | EWT023         |
| <pre>6 LM(I)=2*IX(N,I)-2 7 FEWT02 7 FEW</pre>   | 65       | DC 166                                 | EWT023         |
| DC 200 I=1.4<br>DC 200 K=1.2<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FE   | 66       | LM(I)=2*IX(N,I)-                       | EWT023         |
| DC 200 I=1.4<br>DD 200 K=1.2<br>II = LM(1) + K<br>KK= 2*I-2+K<br>B(II) = R(II) + P(KK)<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 J=1.4<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FE   |          |  | EWT023         |
| DD 200 K=1.2<br>IT=LM(I)+K<br>KK=2*1-2+K<br>E(II)=R(II)+P(KK)<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 J=1.2<br>JJ=LM(J)+L-II+1<br>LL=2*J-2+L<br>IL=2*J-2+L<br>IL=2*J-2+L<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FE   |          | DC 200 I=1.4                           | EWT023         |
| ITT=LM(I)+K<br>KK=2*T-2+K<br>B(II)=B(II)+P(KK)<br>DD 200 J=1.4<br>DD 200 J=1.4<br>DD 200 L=1.2<br>JJ=LM(J)+L-TI+1<br>L1=2*J-2+L<br>L1=2*J-2+L<br>L1=2*J-2+L<br>L1=2*J-2+L<br>L1=2*J-2+L<br>L1=2*J-2+L<br>L1=2*J-2+L<br>L1=2*J-2+L<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02  |          | DO 200 K=1.2                           | EWT023         |
| KK=2*I-2+K       FEWT02         B(II)=B(II)+P(KK)       FEWT02         DD 200 J=1.4       FEWT02         DD 200 L=1.2       JJ=LM(J)+L-II+1         DD 200 L=1.2       JJ=LM(J)+L-II+1         D1 200 L=1.2       FEWT02         JJ=LM(J)+L-II+1       FEWT02         IF (JJ) 200.200.175       FEWT02         FF (ND-JJ) 180.195.195       FEWT02         RSW=1       KSW=1         GD TD 210       FEWT02         FEWT02       FEWT02         FEWT03       FEWT02         FEWT04       FEWT02         FEWT05       FEWT02         FEWT06       FEWT02<   |          | II=LM(I)+K                             | EWT023         |
| <pre>E(II)=R(II)+P(KK) DD 200 J=1.4 DD 200 L=1.2 JJ=LM(J)+L-II+1 I(L=2*J-2+L I(L=2*L I(L=2*J-2+L I(L=2*L I(L=2</pre>   |          | KK=2*[-2+K                             | EWT023         |
| DD 200 J=1.4<br>DD 200 L=1.2<br>JJ=LM(J)+L-II+1<br>LL=2*J-2+L<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT0   |          | = B(II) + P                            | EWT023         |
| DO 200 L=1.2<br>JJ=LM(J)+L-II+1<br>LL=2*J-2+L<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>S0 WRITE (6.2004) N<br>KSW=1<br>KSW=1<br>GO TO 210<br>GO TO 210<br>GO TO 210<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02  |          | DO 200 J=1.4                           | EWT024         |
| JJ=LM(J)+L-II+1<br>LL=2*J-2+L<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>F   |          | DO 200 L=1.2                           | EWT024         |
| LL=2*J-2+L<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FE   |          | JJ=[ M( J) +L-[]+]                     | EWT024         |
| IF (JJ) 200.200.175       FEWT02         75 IF (ND-JJ) 180.195.195       FEWT02         80 WRITE (6.2004) N       FEWT02         KSW=1       FEWT02         60 T0 210       FEWT02         95 A(II.JJ)=A(II.JJ)+S(KK.LL)       FEWT02         00 CONTINUE       FEWT02         10 CONTINUE       FEWT02  |          | k.J−2+L                                | EWT024         |
| 75 IF (ND-JJ) 180.195.195<br>80 WRITE (6.2004) N<br>KSW=1<br>60 T0 210<br>95 A(II.JJ)=A(II.JJ)+S(KK.LL)<br>00 CONTINUE<br>10 CONTINUE<br>10 CONTINUE<br>10 CONTINUE<br>10 CONTINUE<br>16 WT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02  |          | JJ) 200+200-17                         | EWT024         |
| 80 WRITE (6.2004) N<br>KSW=1<br>GD TD 210<br>95 A(II.JJ)=A(II.JJ)+S(KK.LL)<br>00 CONTINUE<br>10 CONTINUE<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02<br>FEWT02   | ~        | IF (ND-JJ) 180.195.19                  | EWT024         |
| KSW=1       FEWT02         GO TO 210       FEWT02         95 A(II.JJ)=A(II.JJ)+S(KK.LL)       FEWT02         00 CONTINUE       FEWT02         10 CONTINUE       FEWT02         16 CONTINUE       FEWT02         17 (KSW.EQ.I) GO TO 500       FEWT02   | $\infty$ | 3                                      | EWT024         |
| GO TO 210       FEWT02         95 A(II.JJ)=A(II.JJ)+S(KK.LL)       FEWT02         00 CONTINUE       FEWT02         10 CONTINUE       FEWT02         16 CONTINUE       FEWT02         17 (KSW.EQ.I) GO TO 500       FEWT02  |          | ¥                                      | EWT024         |
| 95 A(II.JJ)=A(II.JJ)+S(KK.LL)<br>00 CONTINUE<br>10 CONTINUE<br>16 KSW.EQ.1) GD TO 500<br>FEWTO2<br>FEWTO2  |          | GO TO 210                              | EWT024         |
| 00 CONTINUE<br>10 CONTINUE<br>16 KSW.EQ.1) GD TO 500<br>FEWTO2   | 6        | I = A(II + JJ) = A(I                   | EWT024         |
| 10 CONTINUE<br>15(KSW.EQ.1) GD TO 500<br>FEWTO2  | 0        | -                                      | EWT025         |
| F(KSW+E0.1) GD TU 500  |          | CONTINUE                               | EWT025         |
|  |          | F(KSW.EQ.1) GO TO 50                   | EWT025         |

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B(K)=B(K)+UZ(N) B(K-1)=B(K-1)+UR(N) K=2 × N

D0 250 N=1.NUMNP

000

ADD CONCENTRATED FORCES

0000 250 272 271 270 264 260 062 DO 300 L=1.NUMPC CONTINUE 11=2\*1 PRESSURE BEUNDARY CONDITIONS SINA=C.0B(11)=B(11)-RX\*(SINA\*DZ-COSA\*DR) B(II-1)=B(II-1)+RX\*(COSA\*DZ+SINA\*DR)COSA=DCCS(CDDE(1)) SINA=DSIN(CODE(I)) COSA = 1.0SINA=0.0JJ=2\*J 7X=R(I)+2.0\*R(J)  $RX = 2 \cdot 0 R(I) + R(J)$ DR=(R(J)-R(I))\*PP DZ = (Z(I) - Z(J)) + PPPP=PR(L)/6CODE(J) = ICODE(J)CODE(I) = ICODE(I)J = JBC(L)I = IBC(L)COS A=1.0 IF (NUMPC) 260.310.260 IF(CODE(I)) 271,272.272

291

SINA=DSIN(CODE(I))

IF(CODE(J)) 291-292-292

FEWT0258 FEWT0256 FEWT0255 FEWT0254 FEWT0273 FEWT0271 FEWT0265 FEWT0264 FEWT0263 FEWT0262 FEWT0261 FEWT0260 FEWT0259 FEWT0257 FEWT025 FEWT0277 FEWT0276 FEWT0275 FEWT0274 FEWT0272 FEWT0270 FEWT0269 FEWT0268 FEWT0267 FEWT0266 FEWT0283 FEWT0282 FEWT0281 FEWT0280 FEWT0279 FEWT0278 FEWT0288 FEWT0287 FEWT0286 FEWT0285 FEWT0284

|        |      | COSA=DCOS(CODE(I))   | FEWT0289 |
|--------|------|--|----------|
|        | 202  | B(JJ-1)=B(JJ-1)+ZX*(COSA*DZ+SINA*DR)                                   | FEWT0290 |
|        | 2.97 | B(JJ)=B(JJ)-ZX*(SINA*DZ-COSA*DR)                                       | FEWT0291 |
|        | 200  | CONTINUE   | FEWT0292 |
|        |      | CONTINUE   | FEWT0293 |
| С      | 510  | DISPLACEMENT B.C.  | FEWT0294 |
| C<br>C |      | DISPLACEMENT DOCO  | FEWT0295 |
| ι.     |      | DO 400 M=1.NUMNP   | FEWT0296 |
|        |      | U=UR(M)  | FEWT0297 |
|        |      | N=2*M-1  | FEWT0298 |
|        |      | KX = ICODE(M) + 1  | FEWT0299 |
|        |      | GO TO (400,370,390,380).KX   | FEWT0300 |
|        | 270  | CALL MODIFY(N.U.ND2)   | FEWT0301 |
|        | 570  | GO TO 400  | FEWT0302 |
|        | 280  | CALL MODIFY(N+U+ND2)   | FEWT0303 |
|        |      | U=UZ(M)  | FEWT0304 |
|        | 220  | N=N+1  | FEWT0305 |
|        |      | CALL MODIFY(N,U,ND2)   | FEWT0306 |
|        | 400  | CONTINUE   | FEWT0307 |
| С      | +    | CONTINUE   | FEWT0308 |
| U      |      | RETURN   | FEWT0309 |
| С      |      | ``````````````````````````````````````                                 | FEWT0310 |
| C      | 2002 | FORMAT (26HONEGATIVE AREA ELEMENT NO. 14)                              | FEWT0311 |
|        | 2005 | FORMAT (29HOBAND WIDTH EXCEEDS ALLOWABLE 14)                           | FEWT0312 |
| С      |      | ***************************************                                | FEWT0313 |
| C      |      | END  | FEWT0314 |
|        |      | SUBROUTINE QUAC(N.VOL)   | FEWT0315 |
| С      |      | 300A0071AL 30A01A74027   | FEWT0316 |
| L      |      | IMPLICIT REAL*8 (A-H, 0-Z)   | FEWT0317 |
|        |      | IMPLICIT INTEGER*2(I-N)  | FEWT0318 |
|        |      | COMMON STTOP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25),     | FEWT0319 |
|        |      | 1DFPTH(25), E(8,4,25), SIG(7), R(450), Z(450), UR(450), TT(3),         | FEWT0320 |
|        |      | 2 UZ(450),STOTAL(450.4).   | FEWT0321 |
|        |      | 3 T(450). TEMP. 0. KSW   | FEWT0322 |
|        |      | COMMON /INTEGR/ NUMNP, NUMEL, NUMMAT, NDEPTH, NORM, MTYPE, ICODE (450) | FEWT0323 |
|        |      | COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3),               | FEWT0324 |

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| <br>1 HH(6,10),RR(4),ZZ(4),C(4,4),H(6,10),D(6,6),F(6,10),TP(6),XI(6),<br>2 EE(10),IX(450,5) | FEWT0325<br>FEWT0326 |
|---|----------------------|
| COMMON /BANARG/ B(900),A(900,54),MBAND  | FEWT0327             |
| C   | FEWT0328             |
| $I = I \times (N, 1)$   | FEWT0329             |
| $J = I \times (N, 2)$   | FEWT0330             |
| $K = I \times (N, 3)$   | FEWT0331             |
| $L = I \times (N, 4)$   | FEWT0332             |
| C. C  | FEWT0333             |
| I1=1  | FEWT0334             |
| 12=2  | FEWT0335             |
| 13=3  | FEWT0336             |
| 14=4  | FEWT0337             |
| 15=5  | FEWT0338             |
| C THERMAL STRESSES  | FEWT0339             |
| $TEMP = {T(I) + T(J) + T(K) + T(L))/4.0$  | FEWT0340             |
| <br>DO = 103 M = 2.8  | FEWT0341             |
| IF(E(M.1.MTYPE)-TEMP) 103,104,104   | FEWT0342             |
| 103 CONTINUE  | FEWT0343             |
| 104 RATIO=0.0   | FEWT0344             |
| DEN=E(M,1,MTYPE)-E(M-1,1,MTYPE)   | FEWT0345             |
| IF(DEN) = 70,71,70  | FEWT0346             |
| $70 \text{ RATIO} = (\text{TEMP} - \text{E}(M - 1 \cdot 1 \cdot \text{MTYPE}))/\text{DEN}$  | FEWT0347             |
| 70 RATIO-(TEMP-LUM-1-1-MATTEL)) DEN<br>71 DD 105 KK=1-3                                     | FEWT0348             |
| 105 FE(KK)=E(M-1,KK+1,MTYPE)+RATIO*(E(M,KK+1,MTYPE)-E(M-1,KK+1,MTYPE))                      | FEWT0349             |
| TEMP = TEMP = 0   | FEWT0350             |
| · · · · · · · · · · · · · · · · · · ·   | FEWT0351             |
| THE ATTONCHIO   | FEWT0352             |
|   | FEWT0353             |
|   | FEWT0354             |
|   | FEWT0355             |
| CALL MPROP(N)   | FEWT0356             |
|   | FEWT0357             |
| 88  DC 110  M=1.3   | FEWT0358             |
| 110 $TT(M) = (C(M \cdot 1) + C(M \cdot 2) + C(M \cdot 3)) \times EE(3) \times TEMP$         | FEWT0359             |
|   | FEWT036C             |
| C FORM QUADRILATERAL STIFFNESS MATRIX   | ,,                   |

| ب |            | **********                                    | 计存存支持非常有容易的。 计法计算法 计法计算法 计算法 计算法 计算法 计算法 计算法 计算法 计算法 | FFWT0361             |
|---|------------|---|--|----------------------|
|   |            |   |  | ) ( ( <del> </del> ] |
|   | 210        | RR (5) = (R (1) + R (J) + R (K) + R (L)) / 4. |  | EW1030               |
|   |            | ZZ(5)=(Z(I)+Z())+Z(K)+                        |  | EWT036               |
|   |            | 0 94 M=1.4                                    |  | EWT036               |
|   |            | M=IX(N.M)                                     |  | 10                   |
|   |            | F(R(MM).EQ.0AND.ICODE(MM).EQ.0)               | I CODE ( MM ) = I                                    | EWT036               |
|   |            | RR (M)=R (MM)                                 |  | EWT036               |
|   | <b>4</b> 6 | NN)2=   |  | EWTO                 |
| C |            |   |  | EWT036               |
|   |            | <b>}</b> (                                    |  | EWT037               |
|   |            | 0.0   |  | EWT037               |
|   |            | 1)=1.   |  | EWT037               |
|   | 95         | I)=0•   |  | FEWT0373             |
|   |            | 1-11  |  | EWT037               |
|   | 100        | 0 = 0 = 0                                     |  | EWT037               |
|   |            | .) 125,120,12                                 |  | EWT 037              |
|   | 120        | CISTF(11,12,13                                |  | EWT037               |
|   |            | = (RRR(1) + RRR(2) + R                        |  | EWT037               |
|   |            | :(222(1)+222(2)+222(3))/3.                    |  | EWT037               |
|   |            |   |  | EWT038               |
|   |            | GN 10 160                                     |  | EWT038               |
|   | 125        | ~   | -  | EWT038               |
|   |            | (ISTF(I4,I1,I5                                |  | EWT 038              |
|   |            | ).EQ.0  |  | EWT038               |
|   |            | (T)IX+  |  | EWT038               |
|   |            | CISTF(11,12,15                                |  | EWT038               |
|   |            | ).EQ.   |  | EWT038               |
|   |            | (I)IX+  |  | EWT038               |
|   |            | (ISTF(I3,I4,I5)                               |  | EWT038               |
|   |            | ).EQ.0)                                       |  | EWT039               |
|   |            | (1)IX+  |  | EWT039               |
|   |            | <pre>xISTF(12,13,15)</pre>                    |  | 039                  |
|   |            | ).EQ.0)                                       |  | EWT039               |
|   |            | +XI(1)  |  | 1039                 |
| ပ |            |   |  | EWT039               |
|   |            | CO 140 II=1.6                                 |  | WT039                |
|   |            |   |  |                      |

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FEWT0429 FEWT0398 FEWT0399 FEWT0404 FEWT0405 FEWT0406 FEWT0407 FEWT0408 FEWT0409 FEWT0410 FEWT0412 FEWT0413 FEWT0414 FEWT0415 FEWT0416 FEWT0418 FEWT0419 FEWT0422 FEWT0423 FEWT0424 FEWT0425 FEWT0426 FEWT0427 FEWT0428 FEWT0430 FEWT0431 FEWT0432 FEWT0397 F.EWT0400 FEWT0402 FEWT0403 FEWT0411 FEWT0417 FEWT0420 FEWT0401 FEWT0421 STTOP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25), **铅液涂妆或流妆长故故故故意是我说我在这种法故的这种故事的是不是是这些的,这些这些这些这些是是是是是是是是这些的,这些是这些这些的,** 1 HH(6,10),RR(4),ZZ(4),C(4,4),H(6,10),D(6,6),F(6,10),TP(6),XI(6) COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NCEPTH,NORM,MTYPE,ICODE(450) COMMON /ARG/ RRR(5).ZZZ(5).S(10.10).P(10).LM(4).DD(3.3). 1DEPTH(25), E(8,4,25),SIG(7),R(450),Z(450),UR(450),TT(3), COMMON / BANARG/ B(900), A(900, 54), MBAND ELEMENT', I5) SUBROUTINE TRISTF(II, JJ, KK) [MPLICIT REAL\*8 (A-H,0-Z) 2 UZ(450), STOTAL(450,4), HH([I!.JJ)=HH([I..JJ)/4.0 [MPLICIT INTEGER\*2(I-N) FORMAT (\* ZERU AREA 3 T(450).TEMP.0.KSW EE(10), IX(450,5) D0 140 JJ=1.10 INITIAL IZATION RR(2) = RRR(JJ)ZZ(3) = 7ZZ(KK)RR (3) = RRR (KK) RR(4)=RRR(I] [11) Z Z Z = (1) Z Z $\Gamma(1) = 222 = (2) = 222$ 77(4)=777(1] RR(1)=RRR(11 -M12)=JJ II = (I)WM(3)=KK COMMON RETURN \*\*\* FND 140 160 2000 С С  $_{\circ}$  $\cup \cup \cup$ C C

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FEWT0465 FEWT0466 FEWT0467 FEWT0468 FEWT0458 FEWT0459 FEWT0460 FEWT0464 FEWT0455 FEWT0462 FEWT0463 FEWT0452 FEWT0453 FEWT0454 FEWT0456 FEWT0461 FEWT0445 FEWT0446 FEWT0447 FEWT0448 FEWT0449 FEWT0450 FEWT0457 FEWT0435 FEWT0439 FEWT0442 FEWT0443 FEWT0444 FEWT0433 FFWT0434 FEWT0436 FEWT0437 FEWT0438 FEWT0440 FEWT0441 FEWT0451 COMM=RR(2)\*(ZZ(3)-ZZ(1))+RR(1)\*(ZZ(2)-ZZ(3))+RR(3)\*(ZZ(1)-ZZ(2)) D(2,2)=XI(1)\*(C(1,1)+2,0\*C(1,3)+C(3,3)) 00(1.1)=(RR(2)\*ZZ(3)-RR(3)\*ZZ(2))/COMM 00(1.2)=(RR(3)\*ZZ(1)-RR(1)\*ZZ(3))/COMM 00(1,3)=(RR(1)\*ZZ(2)-RR(2)\*7Z(1))/COMM FORM COEEFFICIENT-DISPLACEMENT MATRIX D(3,3)=X1(6)\*C(3,3)+X1(1)\*C(4,4) D(2,3)=XI(4)\*(C(1,3)+C(3,3)) D(2.6)=XI(1)\*(C(1.2)+C(2.3)) D(1.2)=X1(2)\*(C(1.3)+C(3.3)) DD(2,1) = (ZZ(2) - ZZ(3)) / COMM00(2+2)=(ZZ(3)-ZZ(1))/COMM 00(2,3)=(ZZ(1)-ZZ(2))/COMM FORM INTEGRAL (G) T\*(C)\*(G) CALL INTER(XI, RR, ZZ) D(3.5)=XI(1)\*C(4.4) D(1,3)=XI(5)\*C(3,3) D(1.6)=XI(2)\*C(2.3) D(3,6)=X1(4)\*C(2,3) D(6.6)=XI(1)\*C(2.2) D(1,1) = XI(3) \* C(3,3)D(5,5)=D(3,5) $(f \cdot I) = 0(I \cdot f) 0$ DO 110 1=1.6 DO 110 J=1.6 DO 100 J=1.6 DO 100 I=1.6 90 J=1.10 H(I.J)=0.0 0.0=([.])0 F(I,J)=0.020 110 100 С С 00  $\circ \circ \circ \circ$ C ပပ

FEWT0489 FEWT0495 FEWT0496 FEWT0498 FEWT0499 FEWT0500 FEWT0502 FEWT0503 FEWT047C FEWT0486 FEWT0488 FEWT0490 FEWT0492 FEWT0493 FEWT0494 FEWT0497 FEWT0501 FEWT0504 FEWT0469 FEWT0472 FEWT0473 FEWT0474 FEWT0475 FEWT0476 FEWT0478 FEWT0479 FEWT0480 FEWT0482 FEWT0483 FEWT0484 FEWT0485 FEWT0487 FEWT0491 FEWT0471 FEWT0477 FEWT0481 =ORM STIFFNESS MATRIX (H)T\*(D)\*(H) S(I,J)=S(I,J)+H(K,I)\*F(K,J) F(I,J)=F(I,J)+D(I,K)\*H(K,J) DD(3,2)=(RR(1)-RR(3))/COMM DD(3,3)=(RR(2)-RR(1))/COMM 0D(3,1)=(RR(3)-RR(2))/COMM TP(2)=XI(1)\*(TT(1)+TT(3)) (H(K,J)) 128,130,128 (H(K,I)) 138,140,138 TP(1) = XI(2) \* TT(3)TP(3)=XI(4)#TT(3)  $\GammaP(6) = XI(1) * TT(2)$ H(5,J+1)=DD(2,I) H(4.J+1)=DD(1.I) H(6, J+1) = DD(3, 1)H(3, J) = DD(3, I)H(2,J)=DD(2,I) H(1, J) = DD(1, I)DD 139 J=1.10 00 160 I=1,10 130 J=1.10 140 I=1.10 DD 129 I=1.6 140 K=1.6 Dn 130 K=1.6 00 160 K=1.6 DO 120 I=1.3 J=2\*LM(I)-I TP(4) = 0.0TP(5) = 0.0CONTINUE CONTINUE u... 00 Ľ 00 129 130 139 140 120 128 138 ¢  $\odot$  $\cup \cup \cup$ 

FEWT0536 FEWT0538 FEWT0539 FEWT0540 FEWT0506 FEWT0526 FEWT0529 FEWT0532 FEWT0534 FEWT0535 FEWT0505 FEWT0507 FEWT0508 FEWT0509 FEWT0510 FEWT0513 FEWT0515 FEWT0516 FEWT0518 FEWT0519 FEWT0520 FEWT0524 FEWT0525 FEWT0528 FEWT0530 FEWT0533 FEWT0537 FEWT0511 FEWT0512 FEWT0514 FEWT0522 FEWT0517 FEWT0521 FEWT0523 FEWT0531 FEWT052 \* STTOP.HED(18).SIGIR(25).SIGIZ(25).GAMMA(25).ZKNOT(25). I HH(6.10).RR(4).ZZ(4).C(4.4).H(6.10).D(6.6).F(6.10).TP(6).XI(6). COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NDEPTH,NORM,MTYPE,ICODE(450) COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3), 10FPTH(25),E(8,4,25),SIG(7),R(450),Z(450),UR(450),TT(3), COMMON /BANARG/ B(900), A(900,54), MBAND FORM STRAIN TRANSFORMATION MATRIX DETERMINE ELASTIC CONSTANTS MPLICIT REAL\*8 (A-H.C-Z) [MPLICIT INTEGER\*2(I-N) 2 UZ(450),STDTAL(450,4), p(I)=p(I)+H(X\*I)\*Tp(K) HH(I.J)=HH(I.J)+H(I.J) SUBROUTINE MPROP(N) 3 T(450), TEMP, 0, KSW 2 EE(10).IX(450.5) DO 410 J=1.10 MTYPE=IX(N.5) 00 410 I=1.6 C(II.JJ)=0.05 JJ=1.4 5 []=]•4  $J=I \times (N,2)$ K = I X (N, 3)I = I X (N, 4) $[= I \times (N, 1)]$ COMMON RETURN UND ND 00 CC 160 410 500 ŝ  $\cup \cup \cup$  $\cup$ C 000

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FEWT0573 FEWT0574 FEWT0575 FEWT0576 FEWT0568 FEWT0569 FEWT0570 FEWT0572 FEWT0566 FEWT0567 FEWT0543 FEWT0544 FEWT0545 FEWT0546 FEWT0548 FEWT0549 FEWT0550 FEWT0552 FEWT0553 FEWT0554 FEWT0555 FEWT0556 FEWT0557 FEWT0558 FEWT0559 FEWT0560 FEWT0562 FEWT0563 FEWT0564 FEWT0565 FEWT0542 FEWT0551 FEWT0561 FEWT0547 FEWT0'57 FEWT0541 COMMEN / BANARG/ B(900). A(900,54). MBAND COEF=EE(1)/(1.-EE(2)-2.\*EE(2)\*EE(2)) FORM STRESS STRAIN RELATIONSHIP SUBROUTINE MODIFY(N,U,ND2) [MPLICIT REAL\*8 (A-H.O-Z) FE(1) = EE(1) \* SIGIZ(MTYPE)IMPLICIT INTEGER#2(I-N) C(4,4)=COEF\*(0.5-EE(2)) [F (NE2-K) 250+240+240 C(1,1) = COEF\*(1,-EE(2))IF (K) 235,235,230  $B(K) = B(K) - \Delta(K, M) * U$ B(K) = B(K) - A(N, M) \* UIF (NORM) 65,75,65 C(1,2)=COEF\*EE(2) C(1,3) = EE(2) \* COEFDO 250 M=2.MBAND C(2,1)=C(1,2)C(2,2)=C(1,1)C(3,3)=C(1,1)C(2,3)=C(1,2] C(3,1)=C(1,3)C(3,2)=C(1,2)A(K.M)=0.0 A(N.1)=1.0 A ( N . M ) = 0.0 CONTINUE K=N+M-1 X = N - N + 1RETURN B(N)=UCND UND 240 60 230 235 250 65 122 Q 000 C

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FEWT0609 FEWT0608 FEWT0610 FEWT0612 FEWT0598 FEWT0606 FEWT0578 FEWT0579 FEWT0580 FEWT0582 FEWT0583 FEWT0584 FEWT0585 FEWT0586 FEWT0588 FEWT0589 FEWT0590 FEWT0592 FEWT0593 FEWT0594 FEWT0595 FEWT0596 FEWT0599 FEWT0600 FEWTC602 FEWT0603 FEWT0604 FEWT0605 FEWT0607 FEWT0611 FEWT0581 FEWT0587 FEWT0591 FEWT0597 FEWT0601 FEWT0577 STTOP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25), COMMON /INTEGR/ NUMNP.NUMEL.NUMMAT.NDEPTH.NORM.MTYPE.ICODE(450) DEPTH(25),E(8,4,25),SIG(7),R(450),Z(450),UR(450),TT(3), B(900), A(900, 54), MBAND REAL\*8 (A-H.O-Z) UZ (450) • STOTAL (450.4) • IF (ND2.LT.I) GD TD 260 INTEGER\*2(I-N) A(I.J)=A(I.J)-C\*A(N,K) IF (N.LE.0) GD TD 500 DD 400 K=2.MBAND T(450), TEMP, 0, KSW SUBROUTINE BANSOL **AACK SUBSTITUTION** DO 260 L=2.MBAND DD 250 K=L.MBAND B(I) = B(I) - C + B(N) $B(N) = B(N) / A(N \cdot 1)$ COMMON / BANARG/ C=A(N.L)/A(N.1) DD 280 N=1.ND2 ND7=2\*NUMNP I MPLICIT A(N,L)=CIMPLICIT  $I = N + \Gamma - I$ COMMCO **RETURN** N=ND2 1=1+1 I = N = NEND **)=**0 260 280 300 250

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FEWT0613 FEWT0614 FEWT0615 FEWT0616 FEWT0617 FEWT0618 FEWT0619 FEWT0620 FEWT0625 FEWT0628 FEWT0629 FEWT0636 FEWT0645 FEWT0646 FEWT0647 FEWT0648 FEWT0623 FEWT0624 FEWT0626 FEWT0630 FEWT0632 FEWT0633 FEWT0634 FEWT0635 FEWT0638 FEWT0640 FEWT0644 FEWT0621 FEWT0622 FEWT0627 FEWT0635 FEWT0642 FEWT0643 FEWT0631 FEWT0641 FEWT063 STTOP, HED(18), SIGIR(25), SIGIZ(25), GAMMA(25), ZKNOT(25), 1 HH(6.10).RR(4).ZZ(4).C(4.4).H(6.10).D(6.6).F(6.10).TP(6).XI(6) COMMON /INTEGR/ NUMNP,NUMEL,NUMMAT,NCEPTH,NORM,MTYPE,ICODE(450) COMMON /ARG/ RRR(5),ZZZ(5),S(10,10),P(10),LM(4),DD(3,3), 10EPTH(25),E(8,4,25),SIG(7),R(450),Z(450),UR(450),TT(3), COMMGN / BANARG/ B(900), A(900, 54), MBAND COMPUTE ELEMENT STRESSES AND STRAINS R R (5) = (R ( I 1 ) + R ( J 1 ) + R ( K 1 ) + R ( L 1 ) ) / 4 • C [MPLICIT REAL\*8 (A-H,0-Z) FIND ELEMENT COORDINATES IF (K1-L1.E0.0) G0 T0 50 SUBROUTINE STRESS(SPLGT) IF (ND2.LT.L) GO TO 400 IMPLICIT INTEGER\*2(I-N) 2 UZ (450), STDTAL (450,4), B(N) = B(N) - A(N, K) \* B(L)3 T(450),TEMP,Q,KSW EE(10), IX(450,5) DO 300 N=1.NUMEL CALL QUAD(N, VOL)  $I = I \times (N \cdot 1)$ K I = I X (N, 3) $J1 = I \times (N \cdot 2)$ []=[X{N,4} GO TO 300 CONTINUE L = N + K - 1COMMON RFTURN CZL 400 500 C Q  $\cup \cup \cup$  $\circ \circ \circ$ C

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FEWT0674 FEWT0675 FEWT0676 FEWT0678 FEWT0679 FEWT0680 FEWT0681 FEWT0682 FEWT0683 **FEWT0684** FEWT0665 FEWT0666 FEWT0668 FEWT0669 FEWT0670 FEWT0672 FEWT0673 FEWT0649 FEWT0650 FEWT0654 FEWT0655 FEWT0656 FEWT0658 FEWT0659 FEWT0660 FEWT0662 FEWT0663 FEWT0664 FEWT0667 FEWT0677 FEWT0653 FEWT0657 FEWT0671 FEWT0651 FEWT0652 FEWT0661 RR(3)=(TP(1)+TP(2)\*RRR(5)+TP(3)\*ZZ(5))/RRR(5) p(9)={S(10.10)\*RR(1)-S(9.10)\*RR(2))/COMM
p(10)=(-S(10.9)\*RR(1)+S(9.9)\*RR(2))/COMM ZZZ(5)=(Z(I1)+Z(J1)+Z(K1)+Z(L1))/4•0 COMM=S(9,9)\*S(10,10)-S(9,10)\*S(10,9) RRR (5) = (R ( II ) + R ( JI ) + R (KI ) ) / 3.0 ZZZ(2)=(Z(1T)+Z(1T)+Z(KT))/3•0 RR(I)=RR(I)-S(I+8,K)\*P(K) TP(I)=TP(I)+HH(I,K)\*P(K) IF (COMM) 155,160,155 RR(4) = TP(3) + TP(5)COMPUTE STRESSES COMPUTE STRAINS  $(1-\Gamma)=B(J-I)$ DO 170 K=1.10 00 170 I=1.6 DO 150 K=1,8 DO 150 I=1.2 RR(1)=P(1+8) DO 120 I=1.4 JJ=2\*IX(N,I) RR(2)=TP(6)  $(\Gamma\Gamma) = B(JJ)$ RR(1)=TP(2)  $\Gamma P(I) = 0.0$ P(10) = 0.0GO TO 100  $0 \cdot (0) = (0 \cdot 0)$ [ ] = 2 \* ] 170 160 50 100 120 130 150 155 ပပ C C  $\cup \cup \cup$ C C

| N N                                |   | nnr                                    | ר  |   |                                      | າດດ    | C  | 000   | C                                       |
|------------------------------------|---|--|--|---|--------------------------------------|--------|--|-------|---|
| 000                                | 615<br>300  |  | 530<br>530   | فسو                                     | 500                                  |        |  | 1 aO  |   |
| ORMAT<br>• 4X. •<br>ORMAT<br>FTURN | IF(N.NE.1) GO TO 615<br>WRITE (6.2000)<br>WRITE (6.2001) N.RRR(5).ZZZ(5).(SIG(I).I=1.4)<br>CONTINUE | ###################################### | G=DATAN2(SIG(4)。BB)/2。0<br>G(8)=57。396#ANG<br>G(7)=(SIG(5)-SIG(6))/2。0 | ((SIG(4).NE.C.).OR.(8<br>=0.0<br>TD 530 | ************************************ |        | (SIG(1)+<br>(SIG(1)-<br>DSORT(BE<br>(5)=CC+C | UTE P | 0 180 I=1.4<br>IG(I)=0.0<br>I 180 K=1.4 |
| EWT071<br>EWT071<br>EWT071         | EWT071<br>EWT071<br>EWT071  | EWT071<br>EWT071                       | EW1070<br>EW1070   | EWTO70                                  | EWT070                               | EWT069 | FEW10692<br>FEW10693<br>FEW10695<br>FEW10695 |       | EWT068                                  |

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FEWT0755 FEWT0753 FEWT0754 FEWT0756 FEWT0736 FEWT0738 FEWT0735 FEWT0740 FEWT0742 FEWT0743 FEWT0744 FEWT0745 FEWT0746 FEWT0748 FEWT0749 FEWT0750 FEWT0751 FEWT0752 FEWT0726 FEWT0728 FEWT0729 FEWT0730 FEWT0733 FEWT0734 FEWT0735 FEWT0737 FEWT0747 FEWT0723 FEWT0724 FEWT0725 FEWT0741 FEWT0722 FEWT0727 FEWT0732 FEWT0721 FEWT0731 ARE 4=•5\*(RR(1)\*(ZZ(2)-ZZ(3))+RR(2)\*(ZZ(3)-ZZ(1))+RR(3)\*(ZZ(1)-ZZ(2 R(J)=XX(9)\*RR(I)+(1.-XX(9))\*R(7) Z([)=XX(8)\*ZZ(])+(]-XX(8))\*Z(7) Z{ ] ]=XX( 6) \*Z [ ] )+( ] \*Z ( 6) ] \*Z ( 2) R(I)=XX(8)\*RR(I)+(I.-XX(8))\*R(7) DIMENSION XM(7),R(7),Z(7),X(9) JIMENSIGN RR(1), ZZ(1), XI(1) Z(7)=(ZZ(1)+ZZ(2)+ZZ(3))/3• R(7)=(RR(1)+RR(2)+RR(3))/3. SUBROUTINE INTER(XI, RR, ZZ) WPLICIT REAL\*8 (A-H.C-Z) MPLICIT INTEGER\*2(I-N) XX(1)=.1259391805448 XX(4)=.1323941527884 XX{8}=\_696140478028 XX(9)=.410426192314 (I)\*\*(I)XX=(I)\*\* 00 100 I=1,3 D0 200 I=1,7 DC 300 I=1.6 D0 400 I=1.7 XX(2) = XX(1) $(1) \times (3) = \times (1)$ (5) = XX(4)XX(6)=XX(4) XX(7)=.225 × I ( I ) =0• J=[+3 ((()))END 300 100 200 C C  $\odot$  $\odot$ C C

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XI (1)=XI(1)+XM(I) XI (2)=XI(2)+XM(I)/R(I) XI (3)=XI(3)+XM(I)/(R(I)\*\*2) XI (4)=XI(4)+XM(I)\*Z(I)/(R(I)\*\*2) XI (5)=XI(5)+XM(I)\*Z(I)/(R(I)\*\*2) XI (6)=XI(6)+XM(I)\*(Z(I)\*\*2)/(R(I)\*\*2) 500 XI (1)=XI(1)\*AREA RETURN

C

END

C

FEWT0759 FEWT0759 FEWT0761 FEWT0761 FEWT0763 FEWT0763 FEWT0765 FEWT0765 FEWT0765

## APPENDIX D

## STEADY STATE HEAT TRANSFER PROGRAM FOR BOLTED JOINT

Program Capacity: 50 nodal points

Output Data:

- (a) Input data
- (b) Inverse of matrix
- (c) Nodal temperature
- (d) Given and calculated augmenting vector and residual error

Input Data Sequence:

- A. Case identification (12A4) followed by two blank cards
- B. Card (I1) with a 1
- C. Card (I7) with dimension of matrix
- D. Card (I1) with a 1
- E. Cards (I1, 3(2I3, E15.8)) with node indices started in the first I3 field followed by conductance between these nodes. Only input from lower node number to higher node number required (since the conductance from node i to j equals the conductance from j to i.) Each card has three groups of z node numbers followed by a conductance value except the last card. Last card could have 1, 2 or 3 groups and has a 1 in column 1.
- F. Cards (I1, 3(I6, E15.8) with number of node followed by conductance from the node to ground node which is at specified temperature. Each card has 3 groups of node number followed by conductance. The II field is skipped except for the last card for ground conductances which can have 1, 2 or 3 fields and the first column has a 1. A

node can be connected to only one ground node.

- G. Same as F above, but code temperature specified for ground node instead of the conductance value.
- H. Same as F above, but code internal power dissipation for the particular node instead of the conductance value.

Listing:

SSHT0008 **SSH T0005** SSHT0006 SSH TOOLO SHT0013 SSHT0014 SSHT0015 **SSHT0016** SSHT0019 SSHT0029 **SSHT0032** SSHT0034 SSHT0035 **SSHT0002 SSHT0003** SSHT0004 **SSHT0007 SSHT0009** SSHTC011 SSHT0012 SHT0017 **S SH TOO 18** SSHT0020 SSHTC022 SSHT0024 **SSHTO025** S S H T C O 2 7 **SSHT0028** SSHT0030 SSHT0033 SSHT0C36 SSH T0023 SSH T0031 SSHT0001 SSH T0021 SSHT002 -റ്റ IDENT(12), A(050,050), AA(050,050), B( 50), BI( JUINT **BOLTED** 50), ACON( 50), TACEN( 50), Q( 50) B(I) = -(Q(I) + ACON(I) + TACON(I))HEAT TRANSFER PROGRAM READ(5,52) K,(I,J,AA(I,J),JM=1,3) READ(5,53) K,(I,TACON(I),JM=1,3] READ(5,53) K,(I,ACON(I),JM=1,3) READ IN COEFF. MATRIX ELEMENTS REAC(5,53) K, (1, Q(1), JM=1,3) FORMAT(I1, 3(213, E15.8)) FORMAT(I1,3(I6,E15.8)) 41 [F(K .NE. 1) GO TO 42 •NE. 1) 60 TO 44 .NE. 1) GU TU 43 .NE. 1) GO TO 45 P KEAD(5,51) K, IDENT WRITE(5,111) IDENT = AA(I,J) FORMAT(IL, 12A4) .NE. 1) GO READ(5,55) N.K I=1,N DC 1000 I=1.N J=I, N TACCN(I) = 0. $\Delta A(I,J) = 0.0$ STFADY STATE **DIMENSION** 50) .RES( FORMAT(I7/I1) 00 5 30 1=1 N = 1,N = 1,N FCRMAT(12A6) WRITE (6,23) ACON(I) = 0.Q(I) = 0.CONTINUE 00 3000 00 1000 (I, L)AA 3 I IF(K IF (K IF(K Γ.(X 00 3 1BC ( 00 101 5 C 500 1000 4 7 111 42 52 43 44 45 2 2 2 3 5  $\odot$ C

SSHTC039 SSHTC049 SSHT0050 SSHT0058 S SH T 0060 **SHT0062** SHT0063 SSHT0065 SSHT0C66 SSHT0069 SSHT0040 SSHT0042 **SSHT0045** SSHT0046 SHT0047 **SSHT0048 SSHT0052** SSHT0053 SSHTCC55 SSHT0056 SSHT0059 SSHT0064 SSHT0067 **S SH T 0068** SSHT0070 SSHTCC72 SSHT0037 SSHT0038 **SSHT0043** S SH T C 044 SSHT0051 SSHT0054 SSHT0057 **SSHT0061** S SH T 00 7 1 SSH T0041 FORMAT(IH1.27X,IH1,12X,IHQ,15X,ICHGRD. COND.,ICX,ICHGRD. TEMP.//) ~ 40X33HBC = AUGMENTING VECTOR CALCULATED FORMAT(IH ,26X,I3,7X,F10.5,10X,F1C.5,10X,F10.5,10X) A(I3,1H,I3,2H)=F10.5,5X))) WRITE(6,25)(1,Q(1),ACON(1),TACON(1),I=1,N) 2 = AUGMENTING VECTCR  $40X21H(A) \approx (T) = (B)$  $I_{1}, J_{1}, A(I_{1}, J), J = I_{1}N$ COEFF. MATRIX // SOLUTION VECTOR I, J, A(I, J), J = I, N40X16HAI = INVERSE OF A  $AA(I,I) = (AA(I,I) + ACGN(I)) * (-I_{\bullet})$ AA(I,I) = AA(I,I) + AA(I,J)IF (JN .EQ. IN) GO TO 2001 U 11 M ATR IX 5 FCRMAT( 1H1,39X17HA 5 H 40X21HB 40X19HT  $= \Delta \Lambda (I, J)$ CALL MAT(N, M, A, B (4( WRITE INVERSE 00 2001 J=1,N 00 + J = 1, N00.3 I = 1, N00 9 I = I, 007 I = 1, NFURMAT(1H / BI(I) = B(I)FOPMAT(1H1 ) WRITE(6,10)( AA(I, I) = 0.WRITE (6,26) WRITE(5,6)( WRITE (6,22) I = I, N WRITE(6,5) ((, 1)A 4 CONTINUE CONTINUE CONT INUE M = 1 t I = NIJN=J 00 00 4  $\mathbf{c}_{i}$ \$ 2001 26 ~ 2000 3000 2 2 2 22 ch  $\infty$ 

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CALCU.AUGMENTING VECTOR I3,2H)=E15.8,2X4H BC(I3,1H,I3,2H)=E15.8 **INVERSE 8** 4 17 WRITE (6,18) (J,1,81(J),J,1,8C(J),RES(J),J=1,N) 18 FGRMAT (25X4H B(I3,1H, I3,2H)=E15.8,2X4H BC(I ļI ļI. OUTPUTA AI(I3,1H,I3,2H)=E15.8))) ഹ AX = 8, WHERE INPUT A = A, INPUT = SIZE OF MATRIX TO BE INVERTED , J = 1, N T(I3,2H)=F10.5,9X)\* \* FDFMAT (1H1, 30X76H AUGMENTING VECTOR OUTPUT B= = BC(I) + (AA(I, J) \* B(J))RES(J) = ABS(BI(J)) - ABS(BC(J))11 A(M, I-1)= A(1, I+1) / TEMP 15 B(J) (N, M, A, B) RESIDUAL ERROR = A(1,2) / TEMP 15B(1) / TEMP 15 DIMENSION A(50,50), B(50) 1.0 / TEMP 15 6XE15.8 /) **،** WRITE SOLUTION VECTOR ы A(1,1) FORMAT(1H / 4(5H (4 ( = N + 1 SUBROUTINE MAT J = 1,N । ट I=2,NI  $00 \ 15 \ J = 1, N$ 00 13 1 = 1, N0.0= WRITE(6,11)( WRITE(6,16) FCEMAT(1H / WR ITE(6,23) FCRMAT(1H1) 11 11 11 TO SOLVE ļI. **CCNTINUE** GC TC 101 CCNT INUE **CCNTINUE** A(M,N1) TENP 15 DC 13 30(1) A ( M, N ) BC(I) E ( M ) END 00 Z Σ 2 ----5 16 ----201 12 [] 3 23

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**SSHTC105** SSHT0106 SSHTC104 SH T0107 SSHT0108 SSHTCC99 SSHT0100 SSHTCL02 SSHT0103 **SSHT0095 SSHT0096** SSHTC097 SSHT0098 SSHTCC89 **SSHT0092 SSHT0093** SFT0101 **SSHT0088** SSHT0090 S SH T 0094 **SSHT0074** SSH T0075 SSHT0C76 SHT0078 **SSHT0079 SHT0080** SSHT0082 **SSHT0083** SSHT0C84 SSFT0085 **SSHT0086** SSHT0087 SSH TC091 SSHT0073 **SSHT0081** SSHT0077

SSHT0128 **SSHT0129** SSH T0139 SSHT0140 SSHT0142 SSHT0110 SSHT0115 **SSHTC124 SSHT0125** SSHT0126 **SSHT0134** SSHT0135 **SSHT0136 SSHT0143** SSH T 01 44 SSH T01 09 SSHT0113 SSHT0114 SSHT0116 SSHT0118 SSHT0119 **SSHT0120 SSHT0122** SSH T0123 SSHT0130 **SSHT0138** SSHT0111 SSHTC112 SSHT0132 SSH T0133 SSHT0137 SSHTC141 SSHT0121 SSHT0127 SSHT0131 SHT011 A(I,J-I)= A(I+1,J+1) - TEMP 6 \* A(M,J-1) 6\* A(M, J-1) A(N,NI) \* B(M) ¥ / TEMP 15 ∳ • Q ¢ 5 5 A(M, I-I) = A(I, I) / TEMP 15TEMP TEMP TEMP A(1,1) / TEMP TEMP TEMP TEMP 15 I 1 T IM ES = A(I+1,1)A(I, J-I) = A(I+I, J)= A(I+1,1)S = A(I+1,2)-TEMP6 B(I+1) = 8(1+1)A(M,I) -TEMP A(M,I B (M) ---1 **ا •** = B(M) TEMP I5 = B(1)DO 100 K=1,NI DO 60 I =1, N1 I=1,N1 J=2,N J=2,N1 DC 65 I=1 •N DO 15 I=1,N 00 51 I=2, N H  $= (I \cdot I) =$ H 11 IJ REPEATS N Ħ Ħ Ħ CONT INUE CONT INUE CONTINUE CONTINUE CONT INUE CONT INUE CONTINUE CONTINUE A(N, I) A(N,I) A(I,N) A( I, N) 9 RETURN ψ (N•₩)√ 00 55 00 10 TEMP 8(I) 00 5 TEMP 3(1) B(N) B(N) 8 (W) END ਼ 100 15 55 09 65 r-H LL \ ŝ

J

## TABLE 1

## Separation Radius Comparison - Single and Two Plate Models

|               |        | R                        | Percent               |                                  |  |
|---------------|--------|--------------------------|-----------------------|----------------------------------|--|
| $\frac{A}{B}$ | B<br>A | Single<br>Plate<br>Model | Two<br>Plate<br>Model | Discrepancy<br>Between<br>Models |  |
|               |        |                          |                       |                                  |  |
| 1             | 3.1    | 4.2                      | 3.7                   | 13.5                             |  |
|               | 2.2    | 3.3                      | 2.7                   | 22.2                             |  |
|               | 1.6    | 2.7                      | 2.1                   | 28.6                             |  |
|               | 1.3    | 2.4                      | 1.7                   | 41.7                             |  |
| .75           | 3.1    | 4.5                      | 3.8                   | <b>18.</b> 5                     |  |
|               | 2.2    | 3.6                      | 2.8                   | 28.9                             |  |
|               | 1.6    | 3.0                      | 2.2                   | 36.4                             |  |
|               | 1.3    | 2.7                      | 2.0                   | 35.0                             |  |
| .5            | 3.1    | 5.1                      | 4.1                   | 24.4                             |  |
|               | 2.2    | 4.2                      | 3.2                   | 31.3                             |  |
|               | 1.6    | 3.6                      | 2.8                   | 28.6                             |  |
|               | 1.3    | 3.3                      | 2.5                   | 32.0                             |  |

(see Figs. 12 - 17)

| TABLE | 2 |
|-------|---|
|-------|---|

| Test and Analytic | al Results : | for Radii of | Separation of | Bolted Plates ( | (see Fig. 5) |
|-------------------|--------------|--------------|---------------|-----------------|--------------|
|-------------------|--------------|--------------|---------------|-----------------|--------------|

|              | D                                   | 2в     | 2.5       | Separation Diameters, 2 R <sub>o</sub> -in. |                       |         |          | % Discrepancy Between<br>Computed Values and |               |  |
|--------------|-------------------------------------|--------|-----------|---|-----------------------|---------|----------|--|---------------|--|
| Case in. in. |                                     |        | "Rubbing  | Test"                                       | Autoradiographic Test |         | Computed | Tested Values                                |               |  |
|              |                                     |        | Range     | Average                                     | Range                 | Average |          | Rub. Test                                    | Autorad. Test |  |
| 1            | .065                                | .422   | .4248     | .45   | .4146                 | . 44    | .488     | 7.8  | 9.8           |  |
| 2            | .124                                | .422   | .5053     | .51   | .46                   | .55     | .554     | 7.9  | .7            |  |
| 3            | .191                                | .422   | .5864     | .62   | .7681                 | .78*    | .620     | 0  | 25.8          |  |
| 4            | .253                                | .422   | .7076     | .72   | .6873                 | .7**    | . 700    | 2.9  | 0             |  |
| 5.           | Unmatch<br>ed Pain<br>.124/<br>.257 | • .422 | .5458     | .56   | -                     | <b></b> | .588     | 4.8  |               |  |
| 6.           | .124                                | 1.0    | 1.06-1.10 | 1.09  | —                     | ·       | 1.104    | 1.3  |               |  |
| 7.           | .191                                | 1.0    | 1.11-1.17 | 1.16  |                       |         | 1.210    | 4.1  |               |  |

\* Original x-ray film shows hole in plate and 0.6 inch diameter zone more distinctly than remainder of area sensitized by the radioactive contamination. Loose radiographic contamination observed during test.

\*\* Assembled and disassembled radioactive and non-radioactive plates without rotating plates relative to each other.

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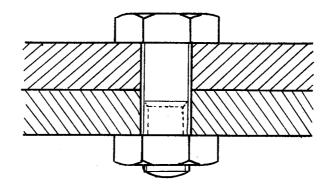


FIG. 1. BOLTED JOINT

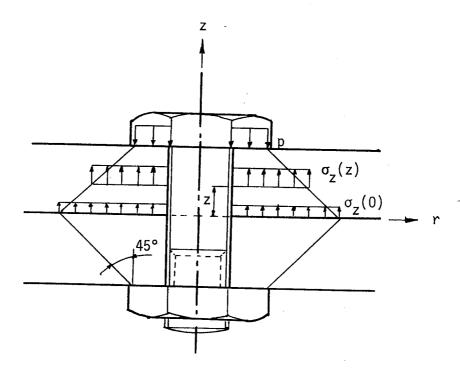


FIG. 2. ROETSCHER'S RULE OF THUMB FOR PRESSURE DISTRIBUTION IN A BOLTED JOINT

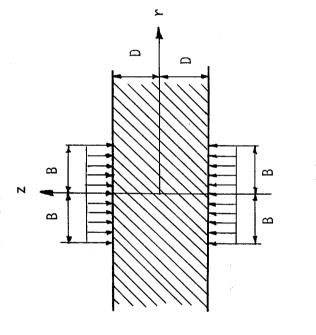
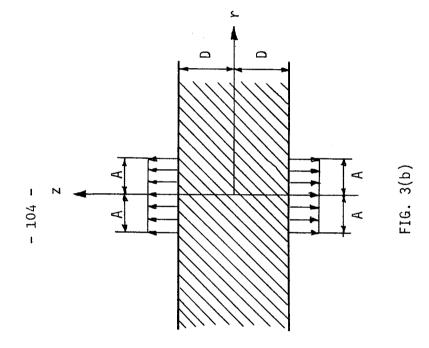
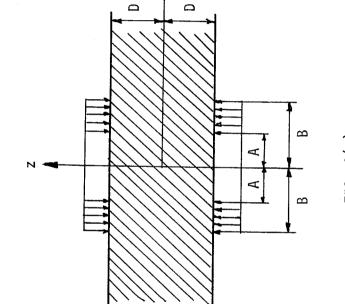


FIG. 3(a)

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FIG. 3(c)

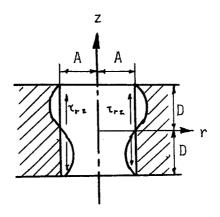


FIG. 3(d)

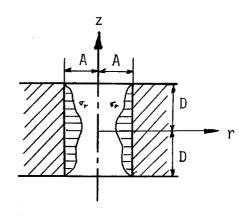


FIG. 3(e)

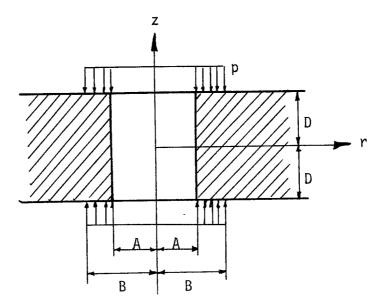
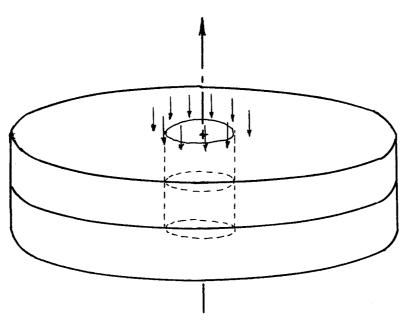
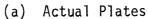


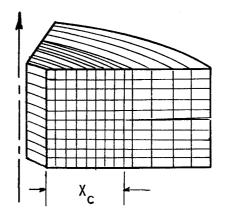
FIG. 3(f)

FIG. 3. FERNLUND'S SEQUENCE OF SUPERPOSITION

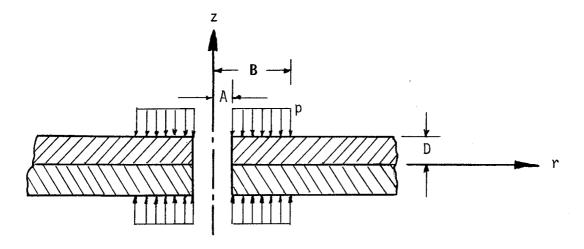


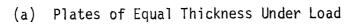


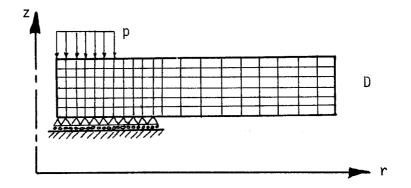
(b) Finite Element
 Idealization



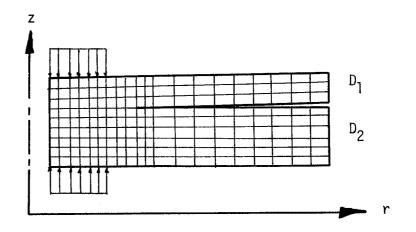
- (c) Single Annular Ring Element
- FIG. 4. FINITE ELEMENT IDEALIZATION OF TWO PLATES IN CONTACT





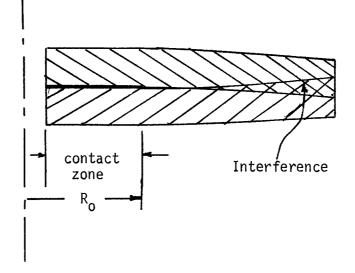


(b) Finite Element Model for Plates of Equal Thickness

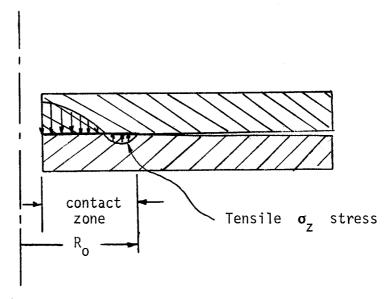


(c) Finite Element Model for Plates of Unequal Thickness

## FIG. 5. FINITE ELEMENT MODELS



(a) Plates Intersect,  $R_0$  too small



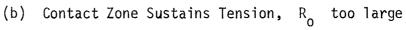


FIG. 6. EXAMPLES OF UNACCEPTABLE SOLUTIONS

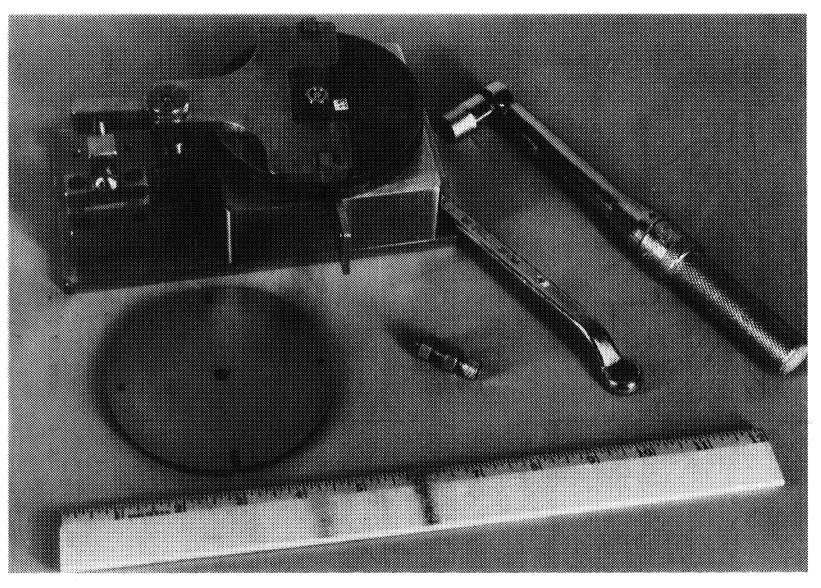


FIG. 7. PLATE SPECIMEN, BOLT AND NUTS, FIXTURE AND TOOLS.

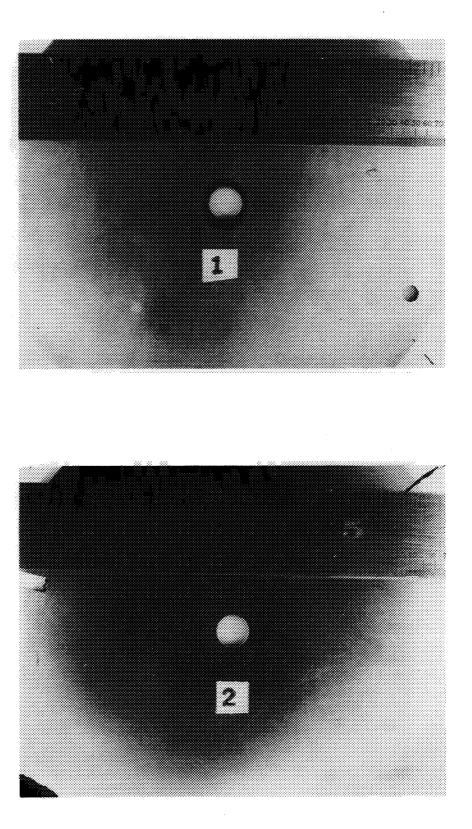


FIG. 8(a). FOOTPRINTS ON MATED PAIR OF 1/16 INCH PLATES.

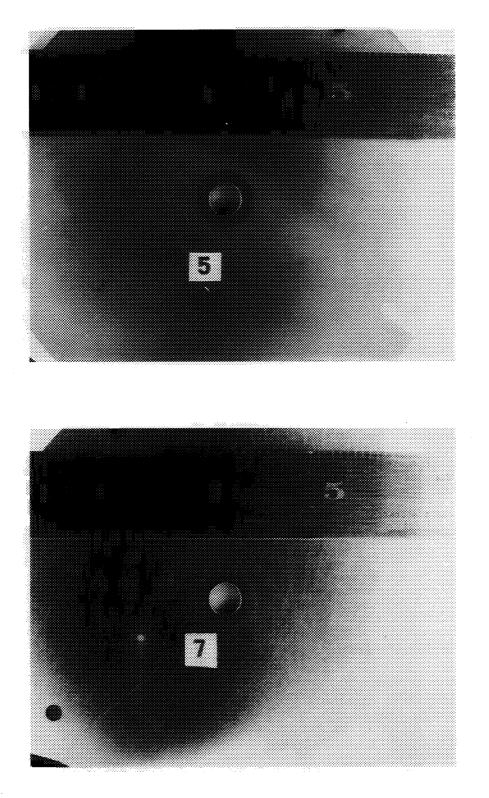


FIG. 8(b). FOOTPRINTS ON MATED PAIR OF 1/8 INCH PLATES.

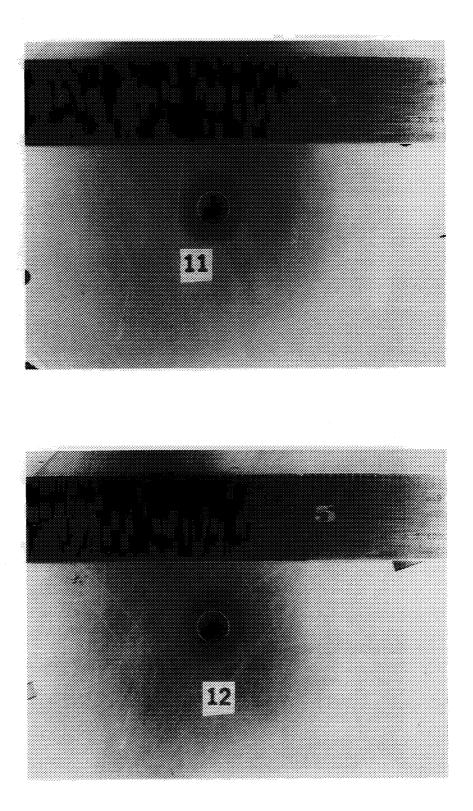


FIG. 8(c). FOOTPRINTS ON MATED PAIR OF 3/16 INCH PLATES.

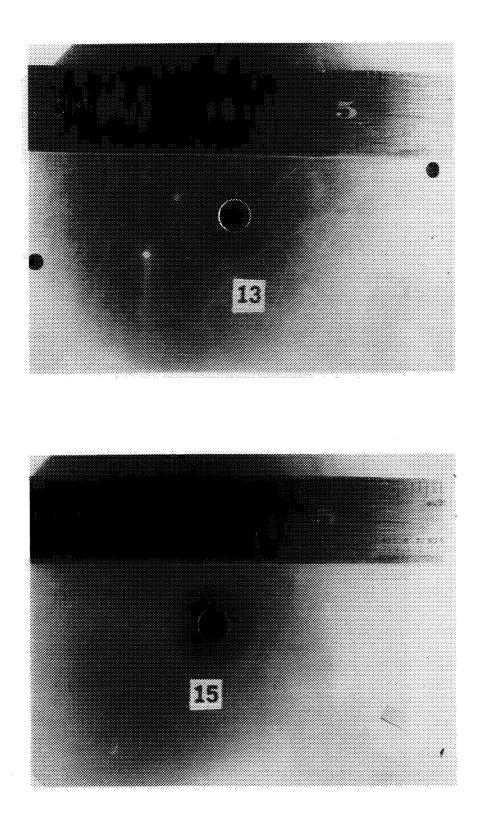
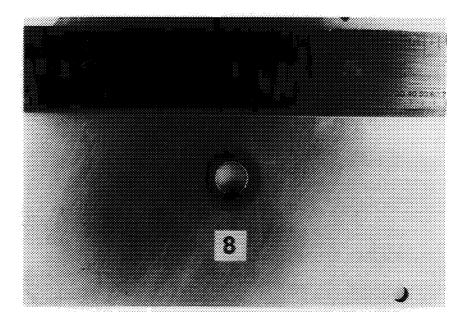


FIG. 8(d). FOOTPRINTS ON MATED PAIR OF 1/4 INCH PLATES.



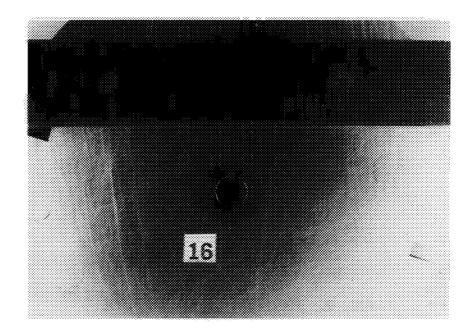


FIG. 8(e). FOOTPRINTS ON MATED PAIR OF 1/8 AND 1/4 INCH PLATES.

FIG. 8. FOOTPRINTS ON THE MATING SURFACES OF 1/16 - 1/16, 1/8 - 1/8, 3/16 - 3/16, 1/4 - 1/4, and 1/8 - 1/4 PAIRS. (A = .128, B = .21)

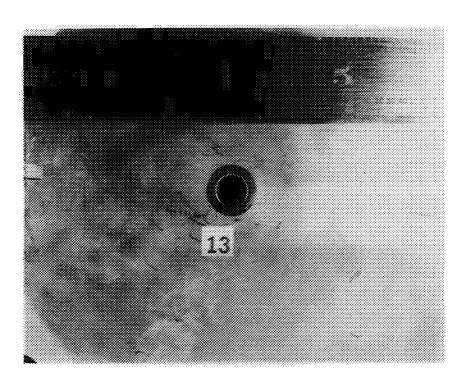


FIG. 9. FOOTPRINT OF NUT ON PLATE.

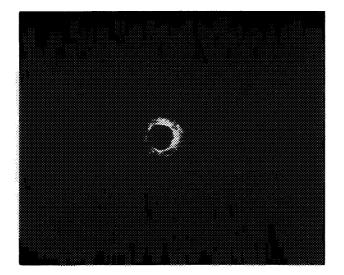


FIG. 10 (a). 1/16 INCH PAIŘ

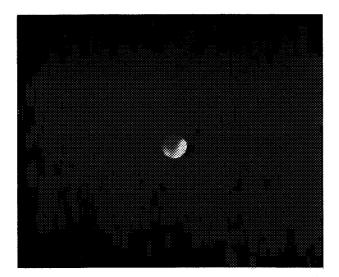


FIG. 10(b). 1/8 INCH PAIR

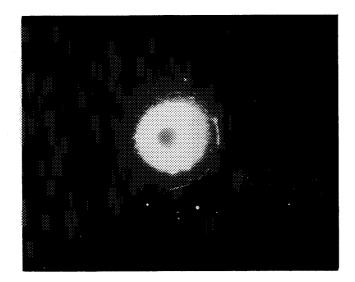


FIG. 10(c). 3/16 INCH PAIR



FIG. 10(d). 1/4 INCH PAIR

FIG. 10. X-RAY PHOTOGRAPHS OF CONTAMINATION TRANSFERRED FROM RADIOACTIVE PLATE TO MATED PLATE. 1/16, 1/4, 3/16, 1/4 INCH PAIRS. (A = .128 in., B = .21 in.)

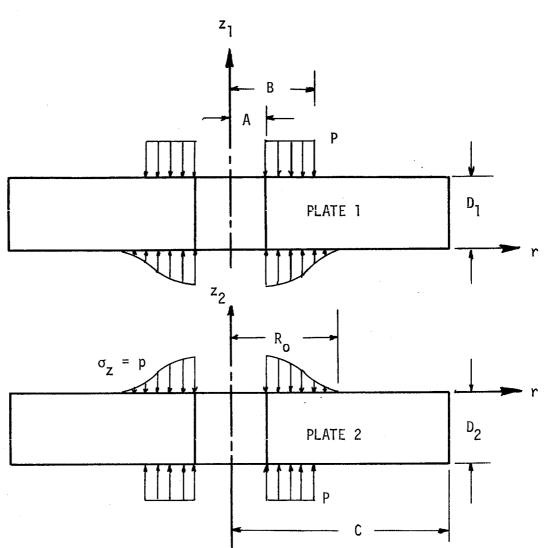
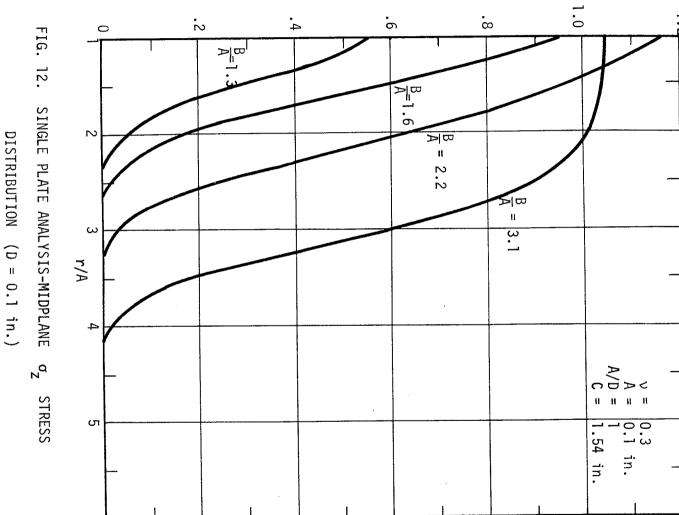


FIG. 11. FREE BODY DIAGRAM FOR TWO PLATES IN CONTACT.



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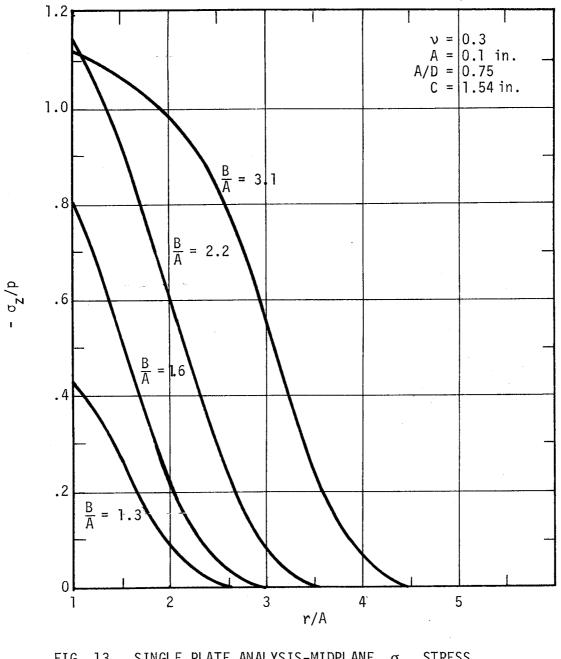
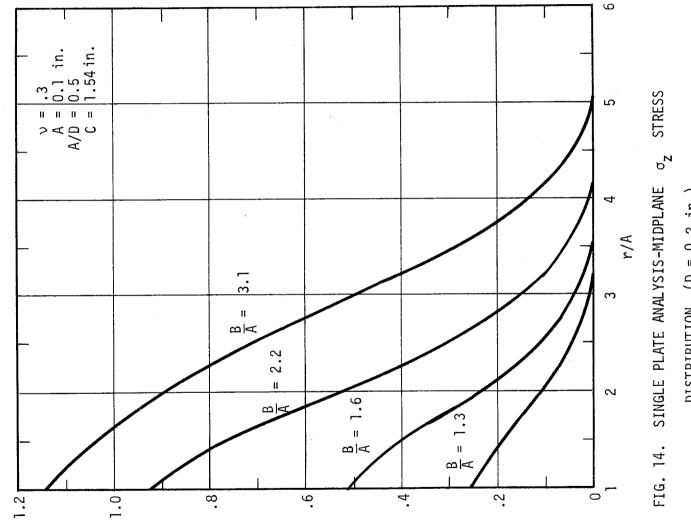


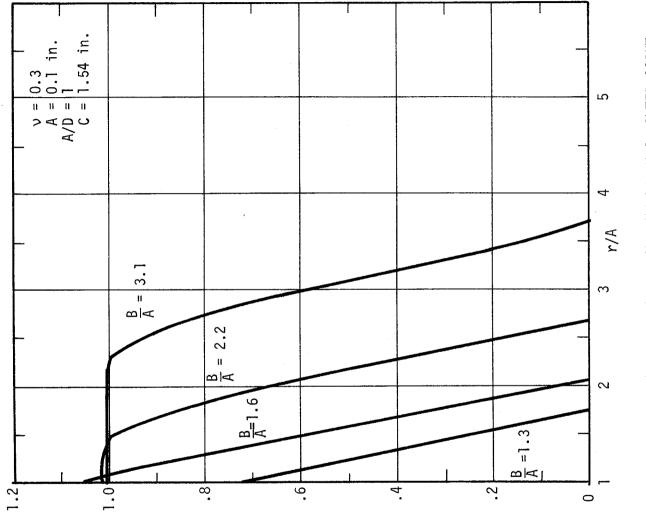
FIG. 13. SINGLE PLATE ANALYSIS-MIDPLANE  $\sigma_z$  STRESS DISTRIBUTION (D = 0.133 in.)



DISTRIBUTION (D = 0.2 in.)

d/<sup>z</sup>o -

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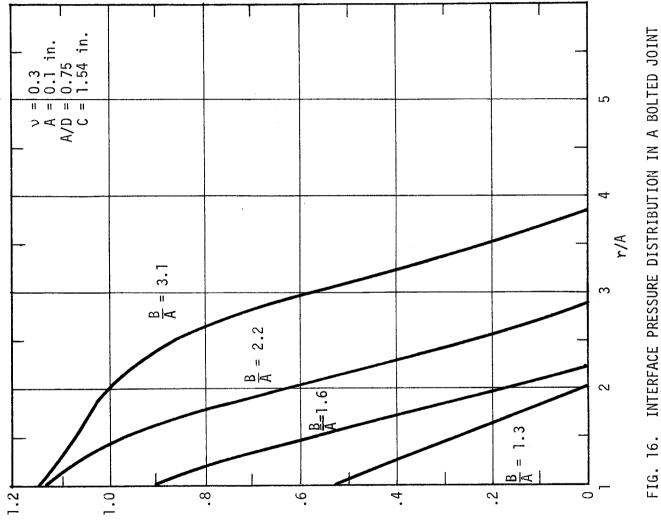
INTERFACE PRESSURE DISTRIBUTION IN A BOLTED JOINT FIG. 15.

(D = 0.1 in.)

77

- م<sup>z</sup>/b

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INTERFACE PRESSURE DISTRIBUTION IN A BOLTED JOINT (D = .133 in.)FIG. 16.

d/<sup>z</sup>o –

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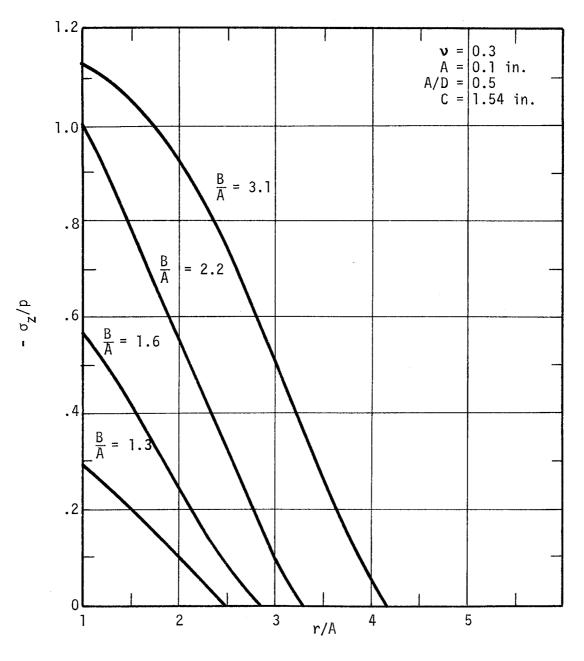
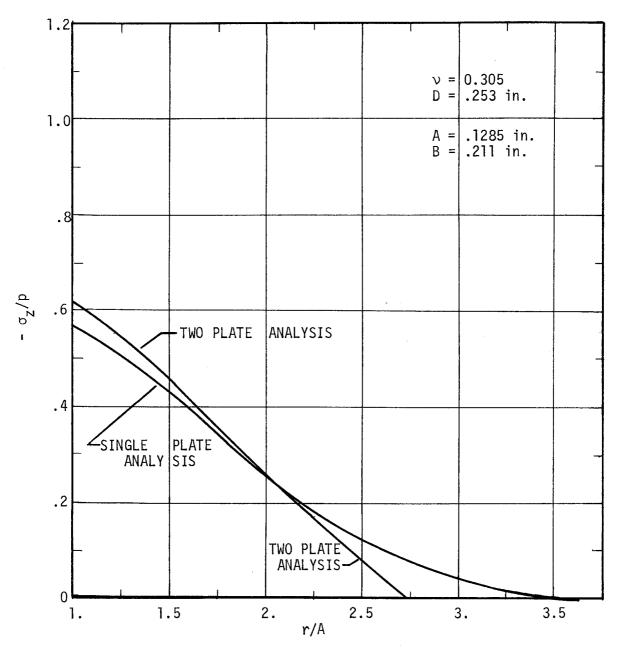
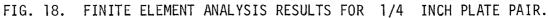


FIG. 17. INTERFACE PRESSURE DISTRIBUTION IN A BOLTED JOINT

(D = 0.2 in.)





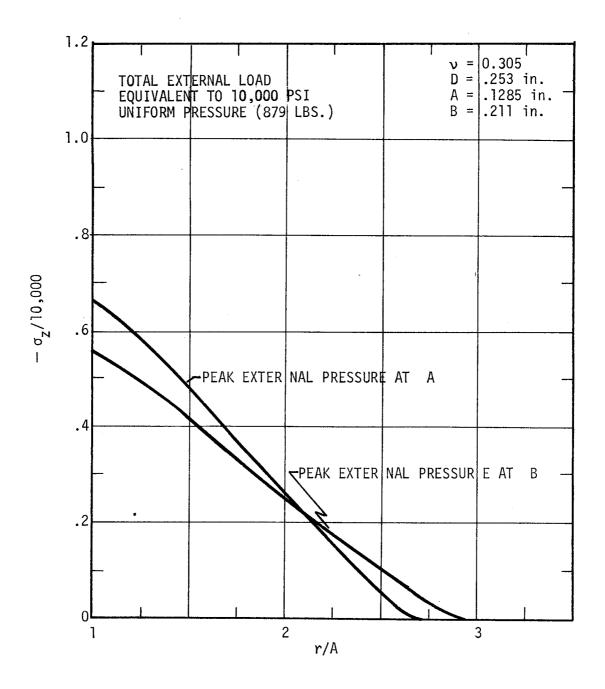


FIG. 19. PRESSURE IN JOINT, TRIANGULAR LOADING

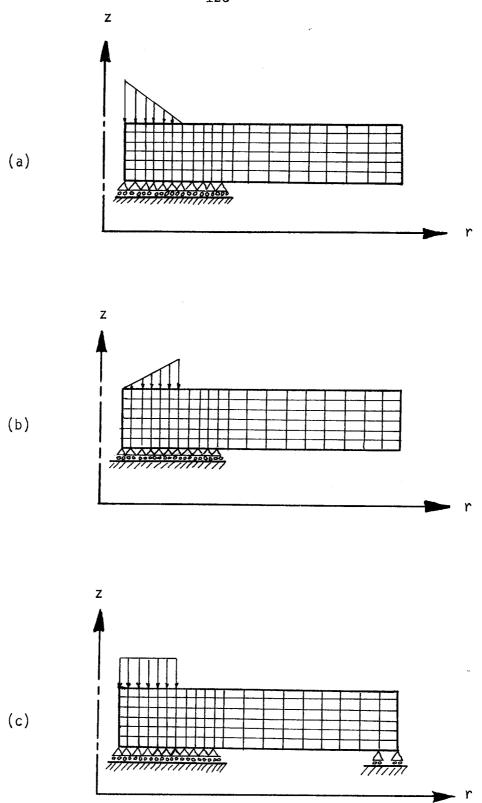


FIG. 20. VARIATIONS OF LOADING AND BOUNDARY CONDITIONS.

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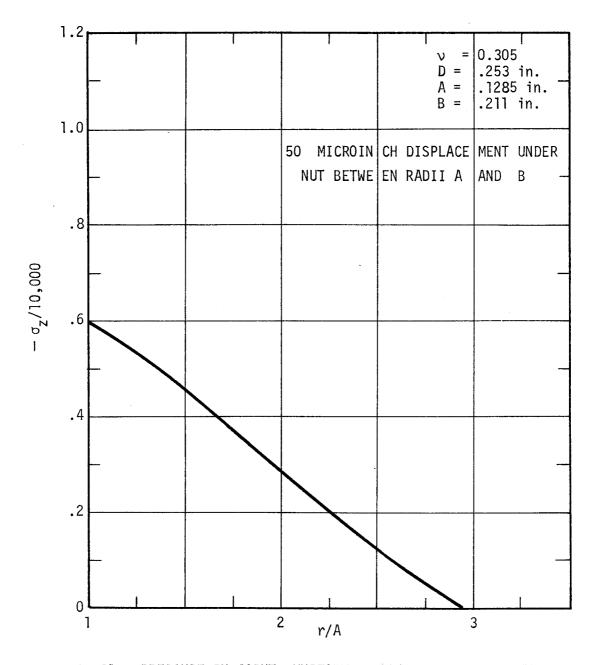


FIG. 21. PRESSURE IN JOINT, UNIFORM DISPLACEMENT UNDER NUT.

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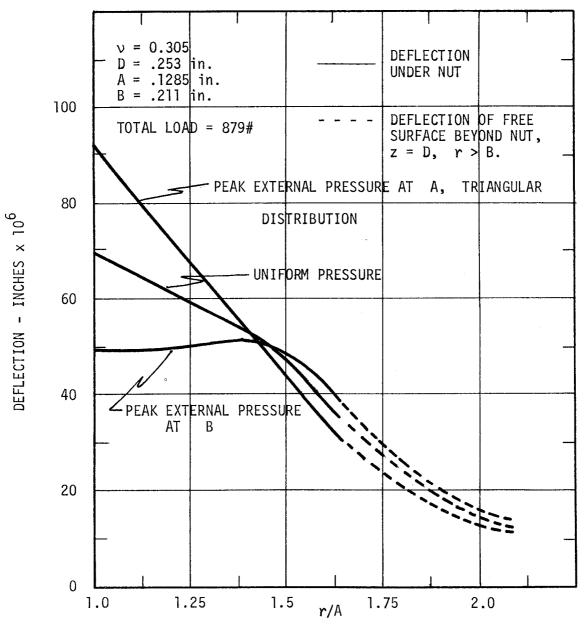
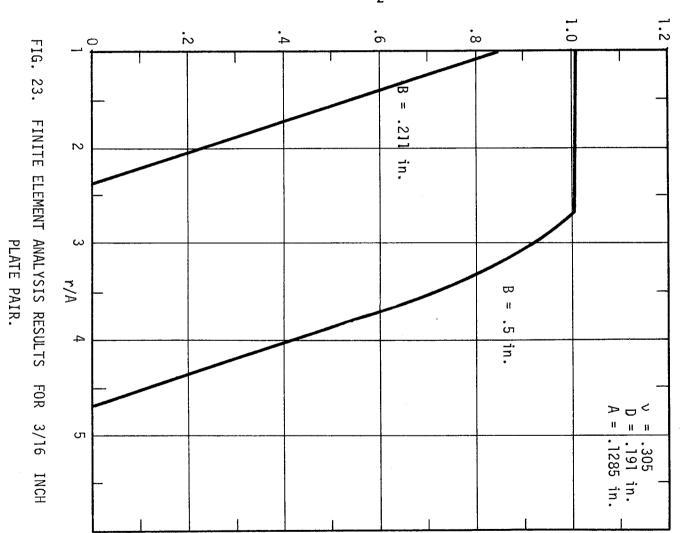


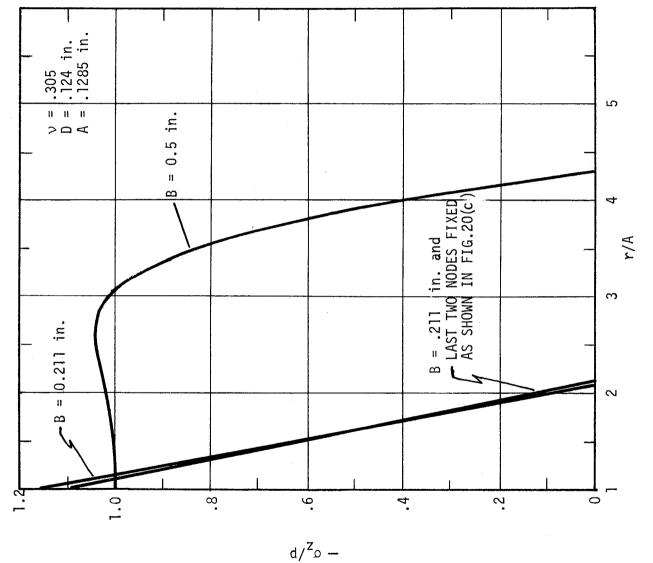
FIG. 22. DEFLECTION OF PLATE UNDER NUT.

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— σ<sub>z</sub>/р

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1/8 INCH PLATE PAIR. FINITE ELEMENT ANALYSIS RESULTS FOR FIG. 24.

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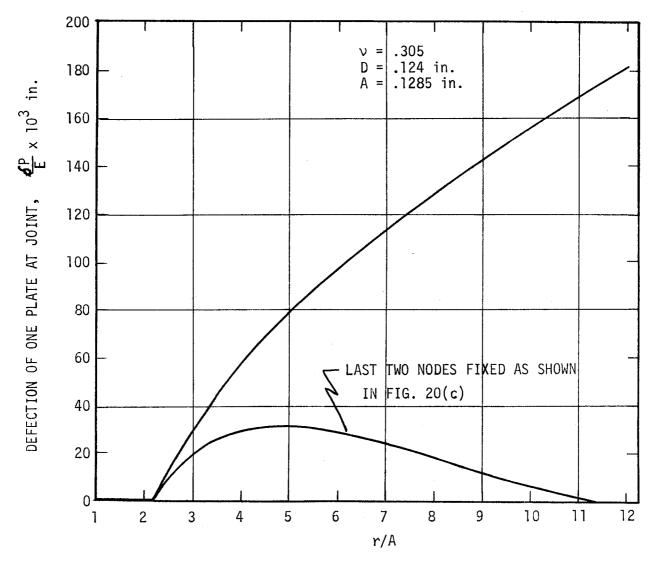
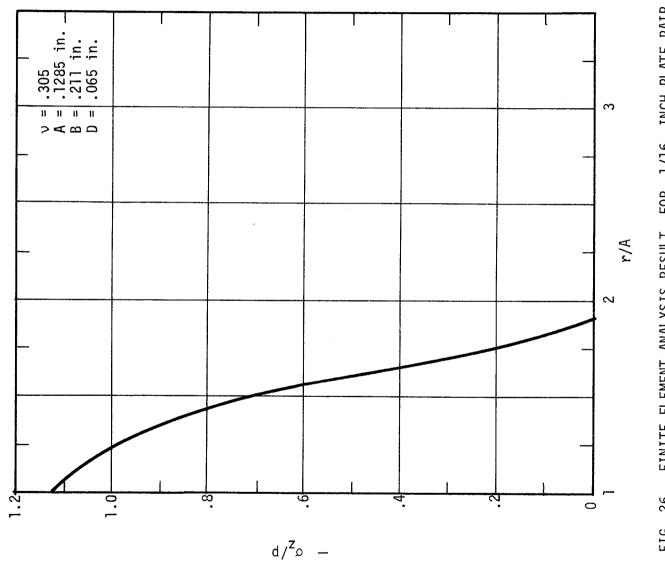


FIG. 25. GAP DEFORMATION FOR FREE AND FIXED EDGES - FINITE ELEMENT ANALYSIS, 1/8 INCH PLATE PAIR.





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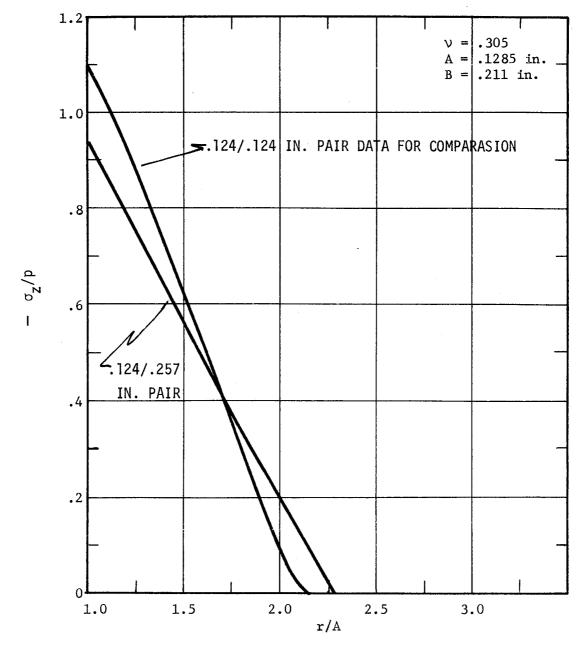
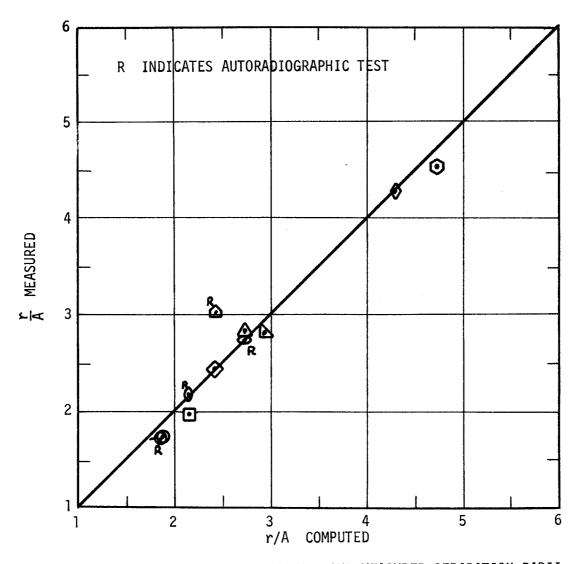


FIG. 27. FINITE ELEMENT ANALYSIS RESULTS FOR 1/8 INCH PLATE MATED WITH 1/4 INCH PLATE.





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