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Monterey, California

THESIS

AN ELASTIC-PLASTIC FINITE ELEMENT ANALYSIS
OF NOTCHED ALUMINUM PANELS

by

Michael John Kaiser

March 1981

Thesis Advisor: G. H. Lindsey

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Finite element, elastic and plastic analyses of various aluminum panels, containing holes and notches, were conducted for comparison with photoelastic experimental results. A FORTRAN IV program, ADINA (Automatic Dynamic Incremental Nonlinear Analysis), was used for both linear and nonlinear analyses. Mesh refinements were used for each panel and the monotonically convergent results were extrapolated using Richardson's method. Stresses were

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Comparisons were made to the elastic, analytic series solution by Howland for a circular hole in a finite strip. The finite element results varied by less than one percent from Howland's solution. Handbook values for the elastic stress concentration factors of the geometries investigated differ from finite element results by less than one percent in all cases. The photoelastic works of Frocht were also compared where applicable. Stresses in the plastic range obtained from slip-line theory for a rigid-perfectly-plastic material show excellent correlation to a finite element analysis of such a material. Comparisons to elastic and plastic experimental data were made for the panels analyzed and show good correlation to finite element results.

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An Elastic-Plastic Finite Element Analysis of Notched Aluminum Panels

by

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Lieutenant Commander, United States Navy
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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

Finite element, elastic and plastic analyses of various aluminum panels, containing holes and notches, were conducted for comparison with photoelastic experimental results. A FORTRAN IV program, ADINA (Automatic Dynamic Incremental Nonlinear Analysis), was used for both linear and nonlinear analyses. Mesh refinements were used for each panel and the monotonically convergent results were extrapolated using Richardson's method. Stresses were locally smoothed from the Gauss integration points to the nodal points. Eight noded, isoparametric elements were used throughout. Modification to an ADINA preprocessor program, also coded in FORTRAN IV, was made for use with a VERSATEC plotter.

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SYMBOLS AND ABBREVIATIONS

ADINA	Automatic Dynamic Incremental Nonlinear Analysis
b	Half width of strip
CPU	Central processor unit
E	Young's Modulus of Elasticity
E_t	Strain hardening tangent modulus
FEA	Finite element analysis
JCL	Job control language
K_T	Stress concentration factor referenced to reduced cross-section σ/σ_n
MVS	Multiple virtual storage
n	Ramberg-Osgood exponent
$O(h^m)$	Order of the discretization error
r	Radius of hole or notch
VM	Virtual machine
β	Ramberg-Osgood coefficient
ε	General representation for strain
λ	Non-dimensional size parameter $\lambda=r/b$
ν	Poisson's Ratio of transverse strain
σ	General representation for stress
σ_θ	Principle stress in θ direction (hoop stress)
σ_r	Principle stress in radial direction
σ_n	Nominal stress in reduced cross-section
σ_∞	Far-field stress
σ_y	Yield stress by 0.2% offset method

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I. INTRODUCTION

Development of on-board fatigue monitoring systems for Naval aircraft have made it possible to record extensive structural loading data in flight. The strain gages used in such a system must be located away from stress concentration areas to prevent their fatigue; however, these areas are of the greatest interest in analyzing and predicting fatigue life of the structure. Understanding the relationship between nominal, far-field stresses and local stresses in critical areas thus becomes vitally important. Recent experimental investigations into the effect of uniform, far-field loads on stress concentration areas have been made at the Naval Postgraduate School (NPS) using photoelastic techniques [Refs. 1, 2 and 3]. These experiments involved loading 7075-T6 aluminum into both the elastic and plastic regions, as well as measurements of residual stresses resulting from plastic yielding.

Finite element analyses (FEA) of the aluminum panels used in the experiments of Stenstrom [Ref. 1] were conducted. The panels used in the experiments of Engle [Ref. 2] and Stuart [Ref. 3] have similar geometry. The finite element programs available at NPS were surveyed and ADINA [Ref. 4] was chosen for its proven ability to produce the nonlinear analyses required for plastic yielding of aluminum. To provide increased accuracy, each panel was modeled using two meshes. The results obtained for the coarse and fine meshes were extrapolated to a final result using the Richardson extrapolation technique [Refs. 5 and 6].

Along with ADINA, a preprocessor program, PSAP1 [Ref. 7], was used to verify mesh connectivity prior to analysis by ADINA. PSAP1 provides a graphical output of the finite element mesh and was coded for the CALCOMP plotter installed at NPS prior to 1978. For this thesis PSAP1 was adapted for use with the VERSATEC plotter now installed at NPS.

The stress-strain material properties of the 7075-T6 aluminum actually used to make the panels had to be established to provide an accurate material model for use with ADINA. Material testing was conducted to establish the Young's Modulus (E), Poisson's Ratio (ν), yield stress (σ_y), strain hardening modulus (E_t) and the Ramberg-Osgood coefficients β and n.

Comparisons were made to other works, in addition to the experiments conducted at NPS. The initial analysis involved a comparison of FEA to the results of Howland [Ref. 8], for a circular hole in a finite strip, to validate the methods used. A comparison of FEA to plane stress, slip-line theory, for rigid-perfectly-plastic material was also included as a validation for the plastic analyses.

II. MATERIAL PROPERTY TESTING OF 7075-T6 ALUMINUM

The elastic and plastic material properties of the aluminum panels were established by tensile tests of uniaxial specimens made from the same mill run. The specimens were manufactured and tested according to current ASTM standards [Ref. 9]. MICRO-MEASUREMENTS, EA-13-125AD-120, precision strain gages with a temperature compensated bridge circuit were used on all specimens. Transverse gage sensitivity errors were corrected according to the manufacturer's recommendations [Ref. 10]. Critical cross-section measurements were made with a micrometer.

A. TESTS FOR AXIAL LOADING

Initial tests of the two-gaged specimen, Fig. 1, in the MTS testing machine indicated a significant bending moment was being produced by the 30,000 lb GRIFF grips. To investigate this problem further, tests were conducted on both the MTS and RIEHLE test machines with a five-gaged specimen shown in Fig. 2. The results of these axial loading tests, shown in Table I, verified that the GRIFF grips on the MTS test machine do not give axial loading. An inspection of the gripped region on the specimen indicated that the jaws of the grip were not applying a uniformly distributed force and thereby induced a bending moment by off-axis loading as shown in Fig. 2. The grips on the RIEHLE test machine gripped evenly and a uniform strain distribution resulted as seen in Table I.

B. CHARACTERISTICS OF 7075-T6 ALUMINUM PANELS

The following characteristic properties were determined from the four specimens tested.

1. Young's Modulus (E)

Tests were conducted using the specimen shown in Fig. 3 on the MTS test machine with 10,000 lb INSTRON grips, which gripped the specimen evenly. The results of testing three specimens are shown in Tables II to IV. Linear regression in the elastic range of all the test results determined a Young's Modulus of 10.12×10^6 psi, with a correlation coefficient of 0.9996.

2. Poisson's Ratio (ν)

Tests were conducted using the specimen shown in Fig. 1 on the RIEHLE test machine with 10,000 lb RIEHLE grips. The results are tabulated in Table V. Linear regression of these results in the elastic region determined Poisson's Ratio to be 0.3256 with a correlation coefficient of 0.99996.

3. Yield Stress and Strain Hardening Modulus

These values, required for ADINA's bi-linear material model, were determined graphically using the data from Tables III and IV. Plastic region data in

Table II is not reliable because of excessive creep encountered during that test.

0.2% offset yield stress, σ_y = 76,000 psi

strain hardening modulus, E_t = 566,000 psi

The graphical fit of these values to the test data can be seen in Fig. 4.

4. <u>Ramberg-Osgood Coefficients</u>

The Ramberg-Osgood equation for elastic-plastic stress-strain characterization is given by:

$$\varepsilon = \frac{\sigma}{E} + \beta\left(\frac{\sigma}{E}\right)^n \tag{1}$$

where:

ε = strain

σ = stress

E = Young's modulus.

The β and n coefficients were determined graphically from the data of Table IV, by the method given by Rivello [Ref. 11]. The data in Table IV gave the following values which are the best fit to the combined test data

$\beta = 1.479 \times 10^{43}$

$n = 21.58$

The graphical fit of these values, in Eq. (1), with the test data is also shown in Fig. 4.

III. MODIFICATION TO GRAPHICAL PREPROCESSOR

The use of a graphical preprocessor program, such as PSAP1, is vital in detecting mesh errors that may otherwise go unnoticed. Establishing the proper node locations and element geometry prior to analysis for a complex code such as ADINA is of utmost importance.

A. PSAP1 MODIFICATIONS

The program PSAP1 was originally coded in FORTRAN IV for use on the NPS IBM 360/370 installation with the CALCOMP Model 765 drum plotter. The CALCOMP system o: installed at NPS used the +Y axis as the unlimited plotting axis, see Fig. 5. The entire plotting logic in PSAP1 uses this orientation of axes to allow multiple plots in a continuous strip. With the VERSATEC Model 8222A electrostatic plotter now installed at NPS, the +X axis becomes the unlimited plotting axis, shown in Fig. 5. To avoid an extensive recoding of PSAP1 for use with the VERSATEC plotter, a simple coordinate transformation of the plot was made in a limited number of short subroutines. First, all installation dependent plotting calls used in PSAP1 were identified. These involved seven plotter functions for which new subroutines were coded.

Function	New Subroutine
Initialize Plotter	CALCMP
Move Plotter Pen	CALPLT
Letter on Plot	NOTATE
Number on Plot	CALNUM
Determine Current Pen Location	CALWH
Draw a Line	CALINE
Stop Plotter	PSTOP

The subroutines listed above merely rotates the plot to coincide with the VERSATEC axis orientation and retain all features originally in PSAP1. Since all plotter hardware code is now isolated in these seven subroutines, future adaptations to other plotting systems is simplified. To provide documentation of this update to PSAP1, a complete listing of the new program is provided in Appendix D.

B. USE OF PSAP1

Previous use of PSAP1 on the IBM 360 system necessitated use of a load module since PSAP1 took over one minute of CPU time to compile. With the new IBM 3033 system compilation requires eight seconds; however, use of a load module or disk stored source code is still recommended since PSAP1 contains roughly 2,500 lines of code. Appendix A contains sample JCL to use PSAP1 on the IBM 3033 MVS system. With minimal effort PSAP1 could also be set up for use on the IBM VM/370 system. The user's manual for PSAP1 is in Ref. 7. In addition to a mesh plot, PSAP1 provides a listing of the node coordinates, element connectivity and several key input values used in execution of ADINA. This information provides a useful check of the input data.

IV. FINITE ELEMENT ANALYSIS (FEA)

A. DESCRIPTION OF MESHES USED

1. Length to Width Ratios and Boundary Conditions

Initial finite element models of specimens had length to width ratios near one, as used by Garske [Ref. 12] for his FEA, but they did not provide the desired uniform distribution at the loading boundary. Specimen length to width ratios of 3-5 were used by Armen, Pifko and Levine [Ref. 13] in their FEA and by Stenstrom [Ref. 1] in his photoelastic experiments. The criteria established to determine uniform boundary stress distribution was uniformity in nodal displacements along the loaded edge as discussed by Segerlind [Ref. 14]. In the models used for FEA in this thesis, nodal displacements were uniform to within 0.1%, and the resulting stress distribution was uniform axially to within 0.1% at the panel ends. In all cases two-dimensional, eight noded, isoparametric elements were used. These higher order elements cannot be loaded in an "intuitive" manner as discussed by Zienkiewicz [Ref. 15, p. 223]. Figure 6 shows the nodal loading required to obtain a uniform surface load.

2. Element Meshes

Two meshes were developed for each panel analyzed. A reasonable effort was made to keep element corner angles as close to 90° as possible to reduce the effect of element distortion discussed by Hopkins and Gifford [Ref. 16]. All meshes modeled a quarter of the actual panel by using the two axes of symmetry as is common practice in FEA. The step from course to fine element meshes was made so that each element in the course mesh was subdivided into four smaller elements of the same type. Such a mesh subdivision can be expected to give monotonic convergence of results, Cook [Ref. 17], and allow extrapolation to results of an infinitely fine mesh. Figures 7 through 13 illustrate the element meshes used in this analysis as plotted by PSAP1.

B. COMPUTATIONAL PROCEDURES

1. Using ADINA

Once the mesh has been developed, input data is prepared in accordance with the ADINA user's manual [Ref. 4]. This same set of data is then used as input for PSAP1 to check for errors and provide a graphical display of the element mesh. After preprocessing by PSAP1, the data is entered into ADINA for analysis. In the case of linear analysis, two types of stress output may be specified, nodal point or Gauss integration point. Nodal point output can be computed for up to eight node point stresses for each element. Since 2x2 Gauss integration was used, four Gauss point stresses were computed for each element. The 2x2 Gauss integration is recognized as the most efficient integration order for this type of analysis [Ref. 15, p. 284]. The linear analysis used an isotropic linear elastic material model (MODEL "1" in Ref. 4) which required input of E and ν material properties. The nonlinear analysis allows only Gauss point stress outputs and uses a bilinear elastic-plastic material model, with von Mises yield condition and isotropic strain hardening (MODEL "8" in Ref. 4).

For static analyses ADINA uses a time function method to apply loads in steps. Linear analysis loading was accomplished in a single step to a nominal value of 3,000 lbs load. Nonlinear analysis loads were applied in ten steps to a maximum value, matching the experimental loads, and then unloaded to zero in ten steps to obtain residual stresses. The stress output from ADINA is a listing of nodal or Gauss point stresses for each element. Since the only area of interest in this analysis was the distribution of stresses along the reduced cross-section, no large post-processing program was developed or used. All final computations using ADINA output data were accomplished on a HEWLETT-PACKARD 9830A calculator, using short programs coded in BASIC. If more extensive stress distribution information were desired, some form of automated post-processing would be necessary to reduce the computational workload. At a minimum, nodal stress outputs by ADINA must be averaged to obtain unique values of stress at nodes shared by more than one element.

2. Richardson Extrapolation

The use of course and fine meshes allows extrapolation to an infinitely fine mesh as discussed earlier. Richardson extrapolation [Ref. 5] was used in this analysis where:

$$\sigma_{extrap} = \frac{\sigma_C (h_F)^m - \sigma_F (h_C)^m}{h_F{}^m - h_C{}^m} \qquad (2)$$

where

σ_{extrap} = extrapolated solution

σ_C = solution obtained with $h=h_C$

σ_F = solution obtained with $h=h_F$

h_C = linear dimension of course element

h_F = linear dimension of fine element

m = 2 (for this analysis)

The exponent m is determined by the order of the discretization error $O(h^m)$. Since h represents the length of an element the element area is represented h^2. In a two dimensional problem such as this $O(h^m)$ is of the order of h^2, the area of an element. In the mesh refinement scheme used $h_F = \frac{1}{2} h_c$ or $\frac{h_F}{h_c} = \frac{1}{2}$. Equation (2) can be rewritten

$$\sigma_{extrap} = \frac{\sigma_c \left(\frac{h_F}{h_c}\right)^2 - \sigma_F \left(\frac{h_c}{h_c}\right)^2}{\left(\frac{h_F}{h_c}\right)^2 - \left(\frac{h_c}{h_c}\right)^2} \tag{3}$$

thus

$$\sigma_{extrap} = \frac{\sigma_F - \frac{1}{4}\sigma_c}{\frac{3}{4}} \tag{4}$$

Equation (4) then becomes the relation to obtain extrapolated stresses from coarse and fine mesh results in a two dimensional analysis. Better extrapolations can be obtained by using three or more refined meshes, but the computational effort increases significantly.

3. Optimal Stress Locations and Local Smoothing

It is generally accepted that the most accurate sampling points for stresses are the Gauss integration points within the element [Ref. 15, p. 281, and Ref 18]. In this analysis, the nodal points are of the greatest interest; thus a technique of local smoothing must be applied to the integration point stresses to obtain nodal stresses as reported by Hinton and Campbell [Ref. 19]. The formulation of this local smoothing technique for ADINA elements is developed in Appendix B. The nodal values obtained must then be averaged if shared by two or more elements.

4. Computational Times

Because of the extremely large size of ADINA (about 17,000 lines of code in the NPS version) and the out of core solver, it does not adapt well to time sharing systems. Using the IBM 360 system at NPS, ADINA required 31 user defined overlays to create a manageable load module in about 30 minutes of CPU time. With the new IBM 3033 MVS system at NPS, ADINA is compiled without overlays in about one minute. When using a load module, the program execution took less than 2 minutes CPU time on the IBM 3033.

In addition to ADINA, the preprocessor (PSAP1) and post-processing techniques involve considerable time and effort. Figure 14 is a flow chart of the computational procedure used in this analysis. An example of the JCL to use ADINA in load module form on the IBM 3033 MVS system with use of the mass storage facilities is shown in Appendix C.

V. RESULTS OF ANALYSIS

A. CIRCULAR HOLES IN LINEAR MATERIAL

The FEA results for a circular hole in a finite width strip were used to validate the elastic computational procedure discussed earlier. The results of Howland [Ref. 8] were compared to both the Gauss point smoothed results and the nodal output results in Fig. 15. The stress concentration factor σ/σ_∞ is referenced to the far-field stress. The smoothed results give the best match to the results of Howland at the edge of the hole, and the only significant variation between the two FEA methods occurs within the first 0.25 inches from the edge. In order to obtain the 0.25 inch stress value for the coarse mesh, in the Gauss point smoothed result, a midside node value had to be obtained by the averaging method discussed in Appendix B. The linear distribution of smoothed stresses along the sides of the element, [Ref. 19], appears to produce a less accurate result in this area of extreme stress gradient, when compared to ADINA's nodal output result. This tendency was noted in all cases; however, the peak stress values from smoothed results consistently gave better correlation with other investigators [Ref. 20].

A circular hole with $\lambda=0.25$ was also analyzed and compared to the experimental results of Stenstrom [Ref. 1] along with an interpolation of Howland's results. The σ_θ experimental data correlates well with the FEA results; however, the σ_r experimental data shows significant variation between 0.125 and 0.375 inches from the edge of the hole, as seen in Fig. 16.

B. OPPOSITE U NOTCHES IN LINEAR MATERIAL

The results for linear analysis are presented in non-dimensional stress concentration form; however, the normalizing stress changes. For U notches K_T is the stress concentration factor referenced to the theoretical, nominal stress (σ_n) in the reduced cross-section where σ_n = Load/Area of Reduced Cross-Section.

1. Shallow Notch Panel

The FEA results plotted with the experimental data of Stenstrom are shown in Fig. 17. Once again both FEA results are shown and the variation for the two methods occur within 0.25 inches from the notch edge; however, there was less variation than was seen in the circular hole analyses.

For this panel the experimental data appear to be uniformly below the FEA results for σ_θ. The σ_r data shows significant variation at the 0.625 inch point but follows the proper trend within 0.5 inches from the notch edge. According to data collected by Peterson [Ref. 20], this notch geometry should yield a maximum K_T = 2.74. The

Gauss point smoothed results matched this value exactly. Stuart [Ref. 3] reported a $K_T = 2.69$ for this same notch geometry, with a standard deviation of 0.187 in the 14 samples he measured by photoelastic methods. Early photoelastic work by Frocht [Ref. 21] determined $K_T = 2.7$ for this notch geometry. The FEA results appear to be in good agreement with other investigators, for this notch geometry.

2. Deep Notch Panel

Results of the FEA for a deep notch were plotted with Stenstrom's experimental data in Fig. 18. The results of the two FEA methods again diverge within 0.5 inches from the notch edge. FEA stress values at the 0.25 inch point have spread farther apart in this case since the stress gradient is very severe at that point. The experimental data correlates well for both σ_θ and σ_r; however, the maximum experimental σ_θ is considerably lower with a $K_T = 3.83$. Results reported by Stuart for this notch geometry was a $K_T = 4.05$ with a standard deviation of 0.219 for 14 specimens measured by photoelastic methods. Frocht [Ref. 22] reported a photoelastic $K_T = 3.9$ for this notch geometry, but concluded that the result was 5-10% low, giving a corrected range of K_T from 4.1 to 4.3. The Gauss smoothed FEA result gave a $K_T = 4.24$ which compares well to an empirical relation given by Peterson [Ref. 20] for $r/d < 0.25$.

$$K_T = \left(1 - \frac{2t}{D}\right)\left(0.78 + 2.243\sqrt{t/r}\right)\left[0.993 + 0.18\,\frac{2t}{D} - 1.06\left(\frac{2t}{D}\right)^2 + 1.71\left(\frac{2t}{D}\right)^3\right] \quad (5)$$

where

t = notch depth (3.9375)

r = notch radius (0.625)

d = minimum width (15.625)

D = maximum width (23.5)

Inserting the values above into Eq. (5) gives a K_T = 4.26, which is 1/2% above the FEA result. Other FEA results reported by Armen, Pifko and Levin [Ref. 13] and Griffis [Ref. 23], using linear strain triangle (LST) elements, produced K_T values within 5% of those produced by use of Eq. (5). The rectangular elements used in this analysis are known to give better results than LST elements as noted by Clough [Ref. 24]. It is clear that the FEA results obtained for this notch are in good agreement with other works.

C. OPPOSITE U NOTCHES IN NONLINEAR MATERIAL

The analysis for loading into the plastic region of the 7075-T6 aluminum was made using the bilinear material model discussed earlier. The loads used were selected to match those used in the experiments of Stenstrom; thus allowing direct comparison. The strains obtained in those experiments were used to solve for stresses by use of the Prandtl-Reuss plastic flow equations.

1. <u>Shallow Notch Panel</u>

The results of FEA for the three load cases, 60,000, 65,000 and 70,000 lbs are presented along with the experimental results in Figs. 19 through 21. The σ_θ results compare well although no trend for peak σ_θ stress away from the notch edge is shown in the experimental data. In all cases the FEA determined the peak σ_θ stress to occur near the yield boundary, and the gradient of the σ_θ stress to fall off dramatically in the plastic zone. This characteristic behavior of the σ_θ stress was reported by other investigators [Refs. 13 and 23] using FEA on 2024-T3 aluminum. Plane elastic-plastic stress distributions reported by Frocht [Ref. 25] show similar trends. The experimental data also shows a marked change in the gradient of σ_θ stress within the plastic region. The growth of this plastic region is approximated using the FEA results for this notch in Figs. 22 through 24.

Experimental data for the σ_r stress distribution matches the FEA results closely except at the notch edge where the measured σ_r does not go to zero as it should. The characteristic peak value of σ_r near the plastic boundary as seen in the FEA results is also shown by the test data.

The FEA residual stress computed upon unloading from the three load cases are shown in Figs. 25 through 30. The characteristic distributions of the σ_θ residual stress agrees with those reported by others [Refs. 25, 26 and 27]. The experimental residual stress distributions reported by Stenstrom show similar trends but significant variations when compared to the FEA results.

2. Deep Notch Panel

Three load cases were computed to plastic loading levels; however, only limited experimental results are available for this notch as seen in Fig. 31. The 30,000 lb load is just at the onset of yield in the notch root area. Limited residual experimental data [Ref. 3] was available for comparison in Figs. 32 and 33 which are plots of the residual σ_θ and σ_r stress distributions as a result of the three loading cases. The 30,000 lb load has caused yielding in a small region at the root of the notch as seen in Fig. 34. Figures 35 and 36 illustrate that the plastic zone does not grow to the extent it did in the shallow notch. The stress gradients are very severe in the deep notch and as a result the 0.25 inch sampling points used in the FEA may be useful in only showing gross trends close to the notch edge. The trends appear to be much the same as in the shallow notch, with the peak σ_θ and σ_r stresses occurring near the yield boundary. The yield boundaries shown in Fig. 31 are approximations based on qualitative analysis of the finite element results. The σ_θ experimental data for the 30,000 lb load case correlates well with the peak stress, again appearing low as it did in the linear analysis. The residual σ_θ stress distribution in Fig. 32 follow much the same trends as seen in the shallow notch but with much higher gradients within the first 0.5 inches from the notch. The FEA results for the residual σ_r stresses shown in Fig. 33 indicate a limitation in the element size used since the σ_r value of the notch edge does not return to zero as it should. Because of this problem the data may be questionable for showing proper trends in the first 0.5 inch from the notch edge.

3. Rigid-Perfectly Plastic Panel

A stress distribution for the theoretical material used in slip-line theory was desired. By using ADINA's bilinear material model such a material could be approximated reasonably well. For this analysis a Young's Modulus (E) of 10^{26} psi was used to model perfect rigidity. The strain hardening modulus (E_t) was set to zero to model perfect plasticity. Poisson's ratio (ν) was 0.4999999, as close to 0.5 as the computer would allow. The $E = 10^{26}$ also represents a computer limit in approaching an infinitely large E. Figure 37 illustrates the results obtained and compares them to a slip-line solution. The results are normalized to the arbitrary 73,000 psi yield stress used in the analysis. The σ_θ values obtained agree exactly with slip-line theory. Conversely the σ_r results do not reflect the same values as slip-line theory, but do show a similar trend. The growth of the plastic zone obtained is shown in Figs. 38 through 40.

VI. CONCLUSIONS AND RECOMMENDATIONS

The results obtained from the FEA have proven useful in determining the validity of experimental data gathered by photoelastic techniques. The FEA results varied by less than 1% when compared to published analytical results and handbook values. Experimental data from Stenstrom's photoelastic work correlated well with the FEA results. The primary exception was the residual stress experimental values, which varied significantly from the FEA results. The variation may be in transforming the residual strains measured photoelastically into stresses for comparison with the FEA results, since ADINA only provides a stress output. Limitations of ADINA's bilinear material model, initially considered severe, do not appear to have hampered this investigation. A possible exception is the residual analyses where the transition region from elastic to plastic strains becomes especially important. The Gauss point smoothed results gave the best correlations at the edge singularities in all cases; however, due to the limitations noted at 0.25 inches from the edge, the results at that specific point may not be as accurate for this method. The nodal output results gave consistently higher stress values at the edge singularities. Because of the severe stress gradients near the deep notch analyzed the use of a finer element mesh near the notch would probably produce better results.

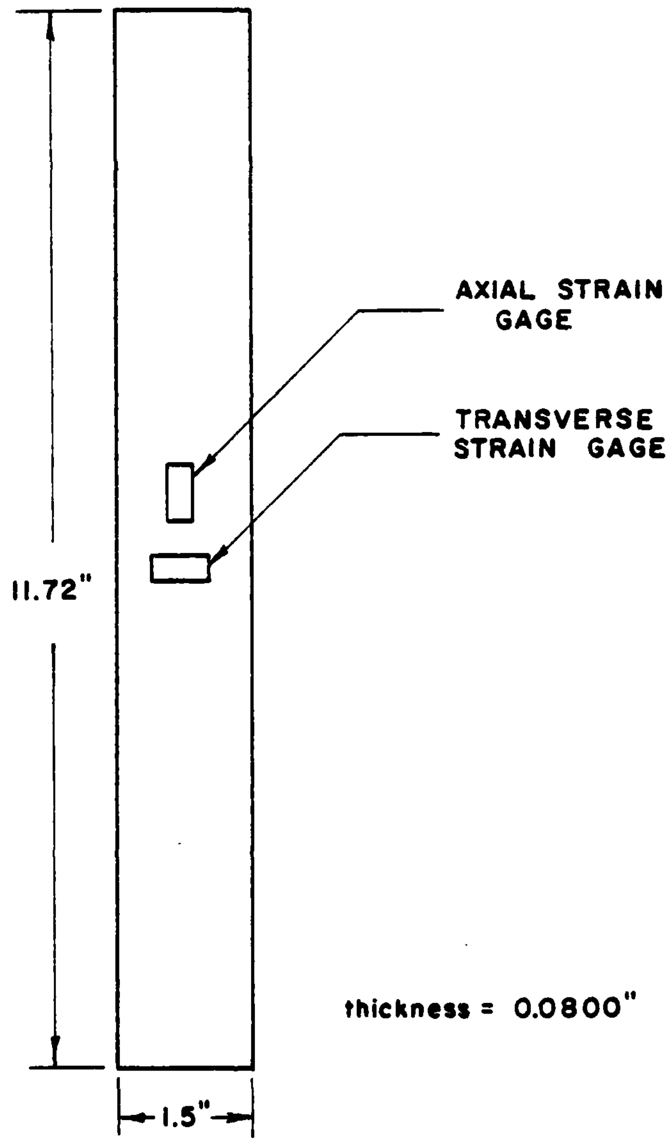
The effort involved in developing two meshes such as those used in this thesis is considerable. An automatic mesh generation capability would reduce the workload and allow experimentation with several types of element meshes.

ADINA proved to be a useful and powerful program, as expected, but something simpler and less awkward to use may be all that is required for two dimensional analysis. Such a system is already in use at NPS but does not offer non-linear capabilities. If use of ADINA is to be continued in this type of investigation, a post-processing program should be adapted. There are programs available to post-process ADINA data at NPS [Refs. 28 and 29] but they would require modifications to work with two dimensional analyses and the VERSATEC plotter.

Standardized material property testing would ease the inevitable task of obtaining basic material properties for use in analysis or experiments. Some form of automatic data collection with use of the MTS testing machine would allow testing of a larger sample population and provide statistically more accurate information.

FIGURE 1

2 GAGE SPECIMEN



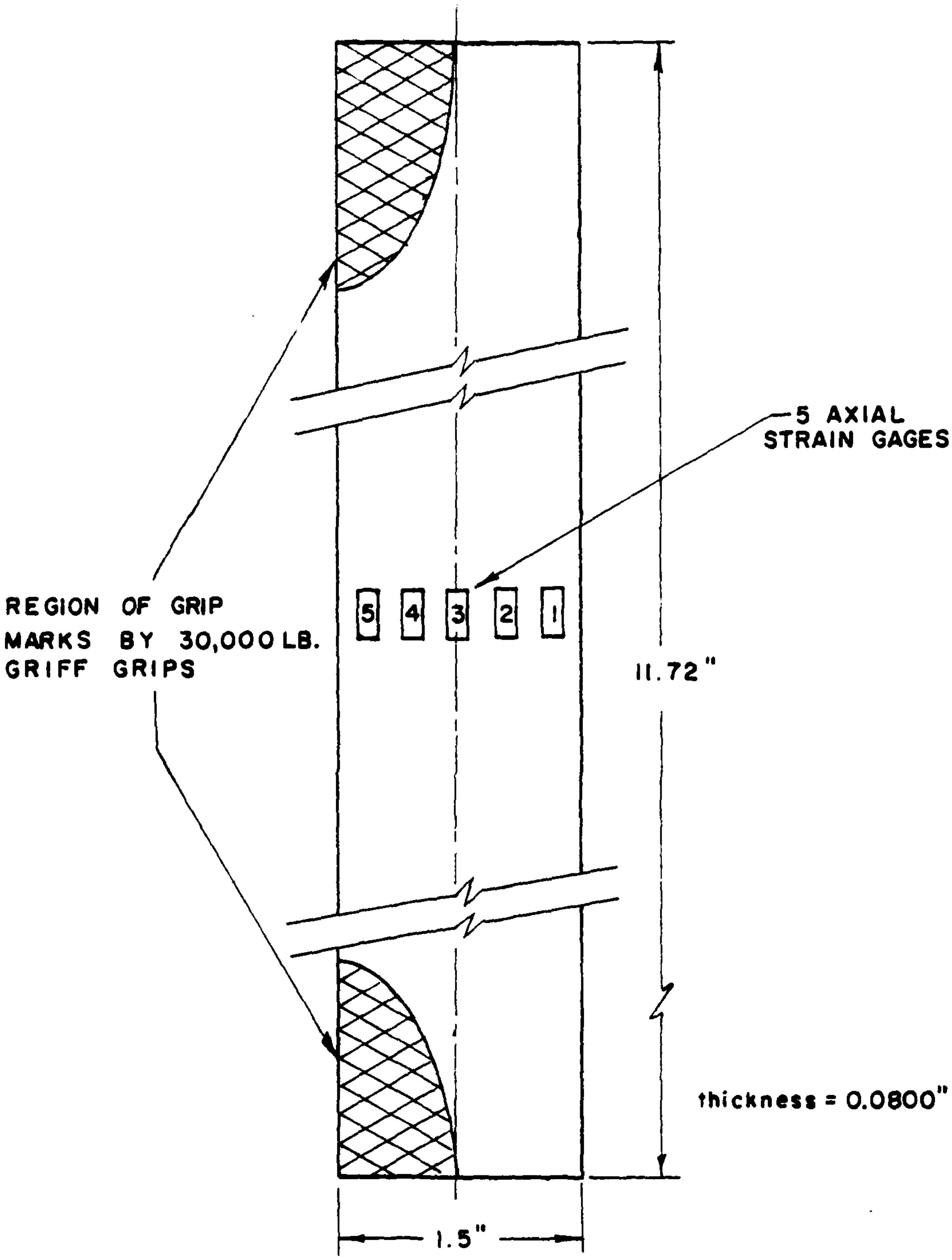


FIGURE 2

5 GAGE SPECIMEN

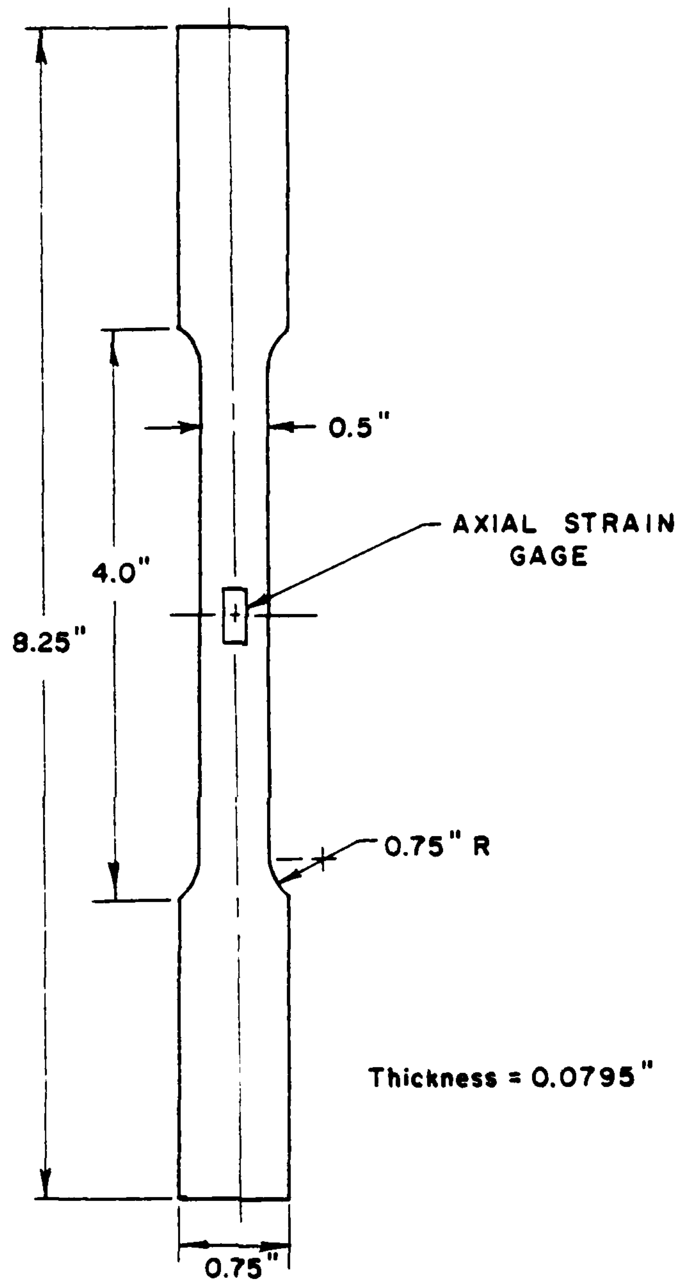
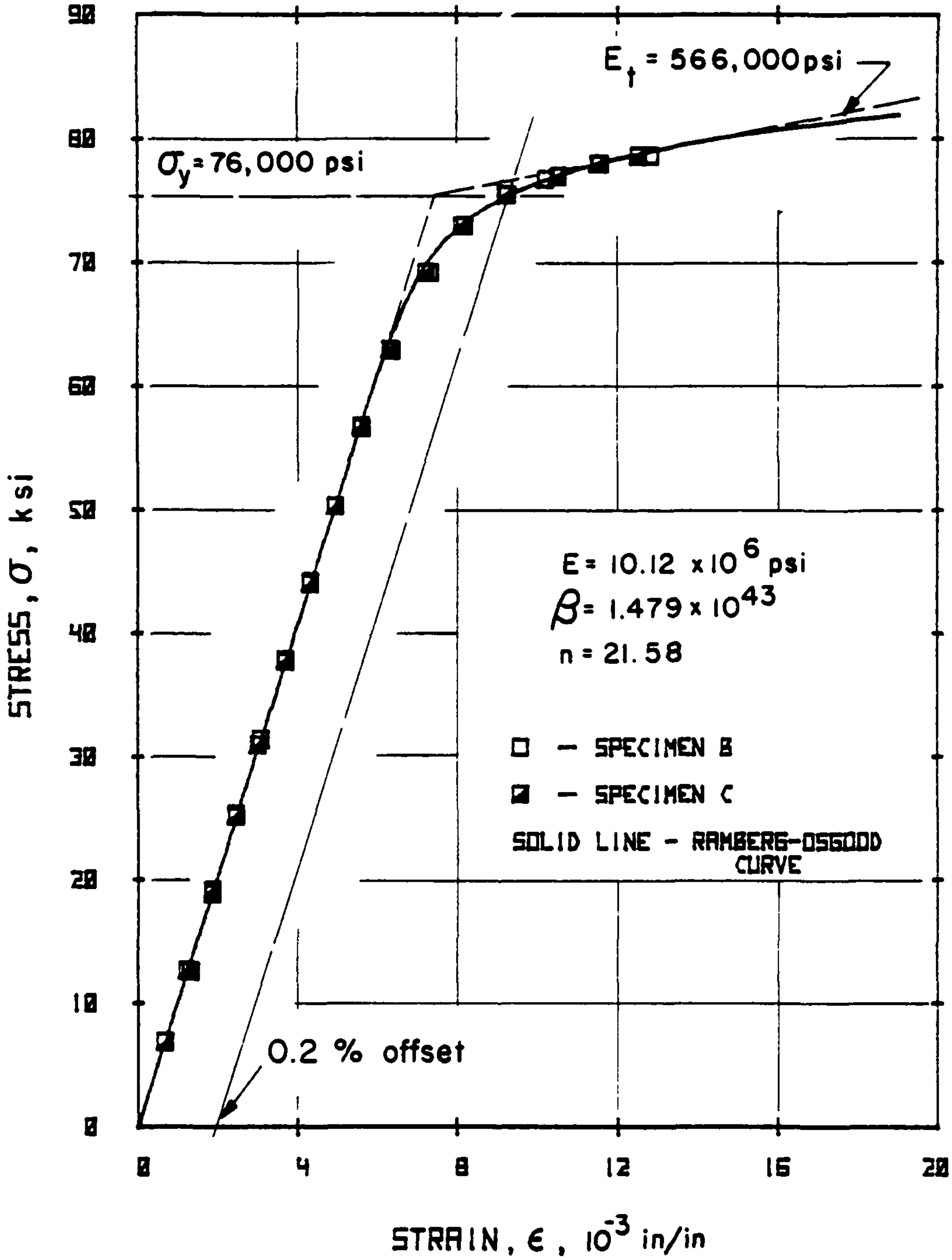


FIGURE 3

1 GAGE SPECIMEN

FIGURE 4

7075-T6 ALUMINUM STRESS-STRAIN CURVE



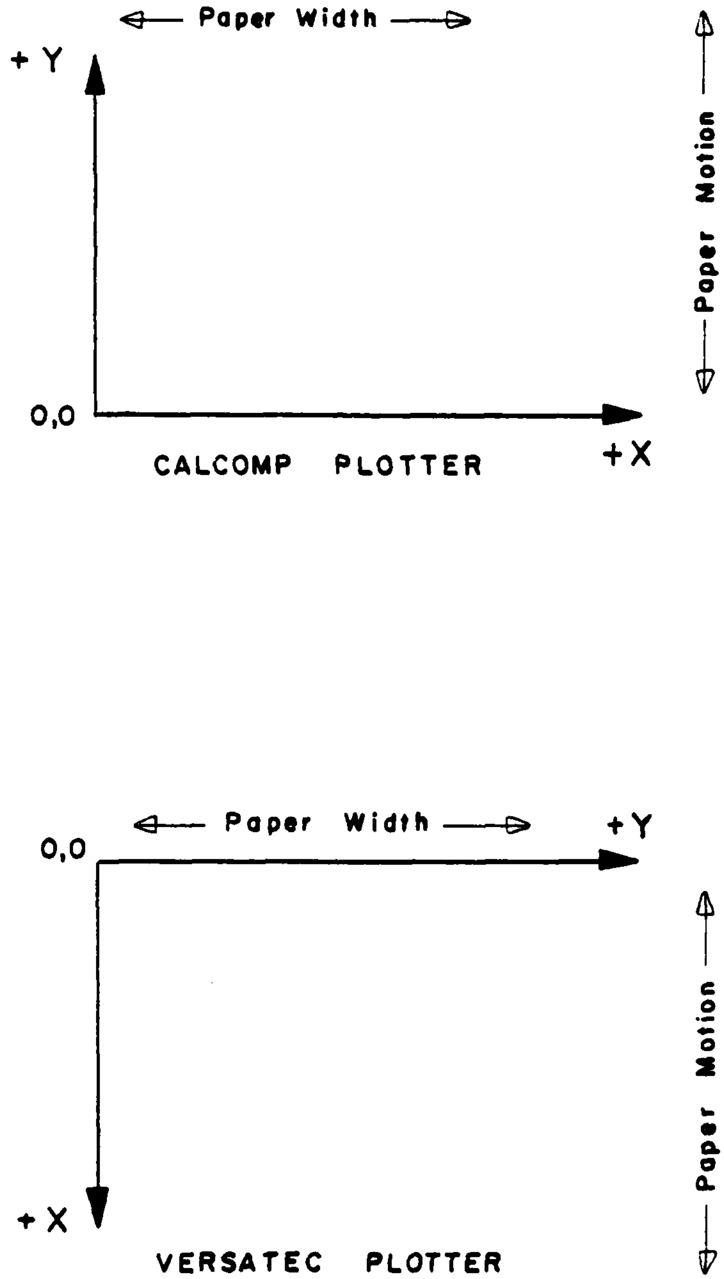


FIGURE 5

CALCOMP AND VERSATEC PLOTTER AXES

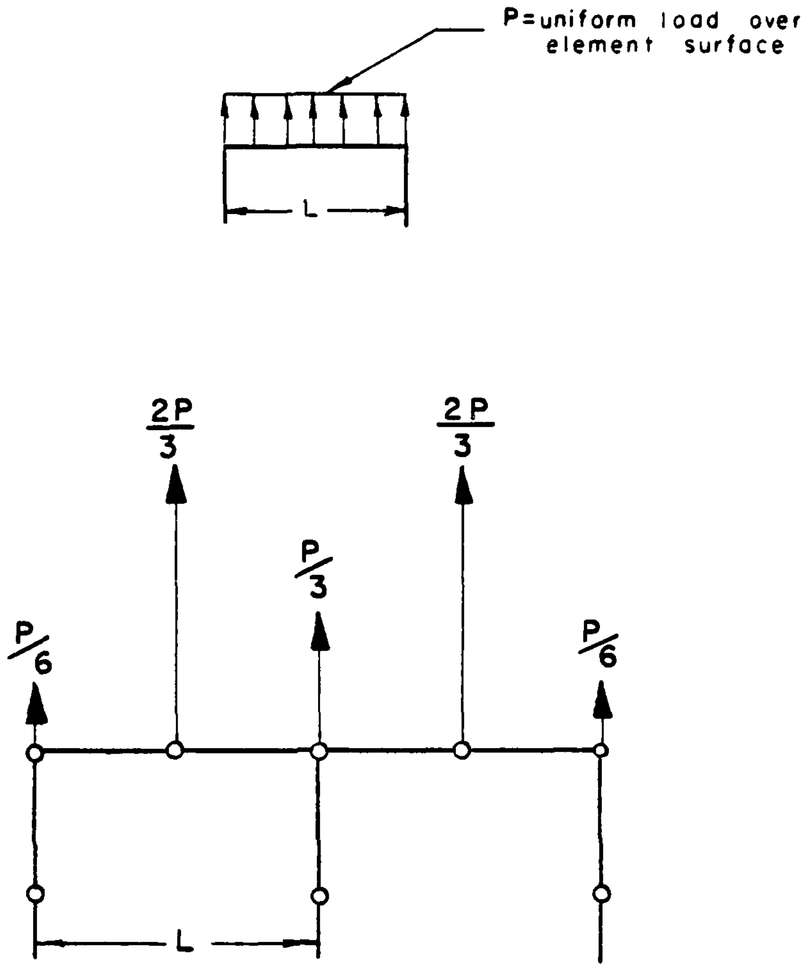


FIGURE 6

NODAL LOADING DIAGRAM

28 ELEMENTS (ISOPARAMETRIC)

111 NODES

192 DEGREES OF FREEDOM

DIMENSIONS

λ	W	L	RADIUS
0.2	5"	25"	1"
0.25	4.0625"	20"	1"

$$\lambda = \frac{\text{RADIUS}}{W}$$

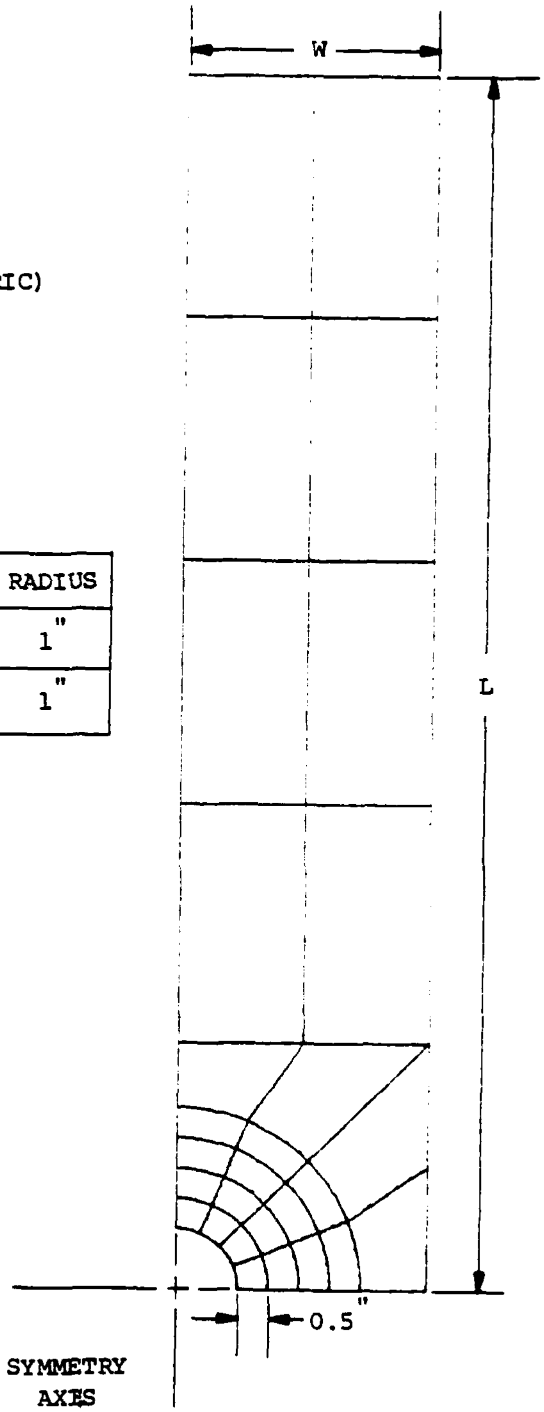


FIGURE 7

COURSE MESH FOR CIRCULAR HOLES

A SUBDIVISION OF COURSE MESH

112 ELEMENTS (ISOPARAMETRIC)

389 NODES

720 DEGREES OF FREEDOM

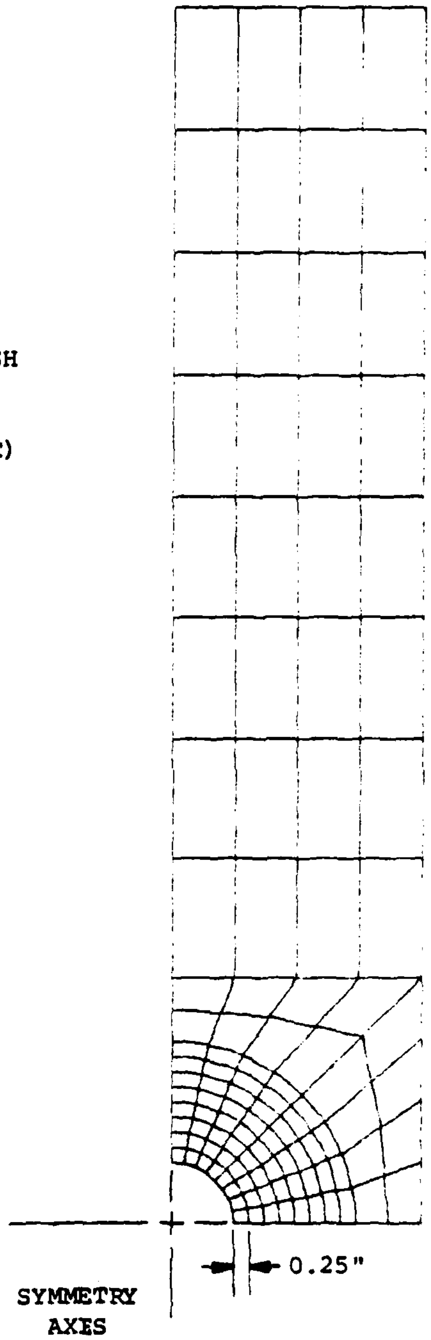


FIGURE 8

FINE MESH FOR CIRCULAR HOLES

FIGURE 9 COURSE MESH FOR SHALLOW NOTCH

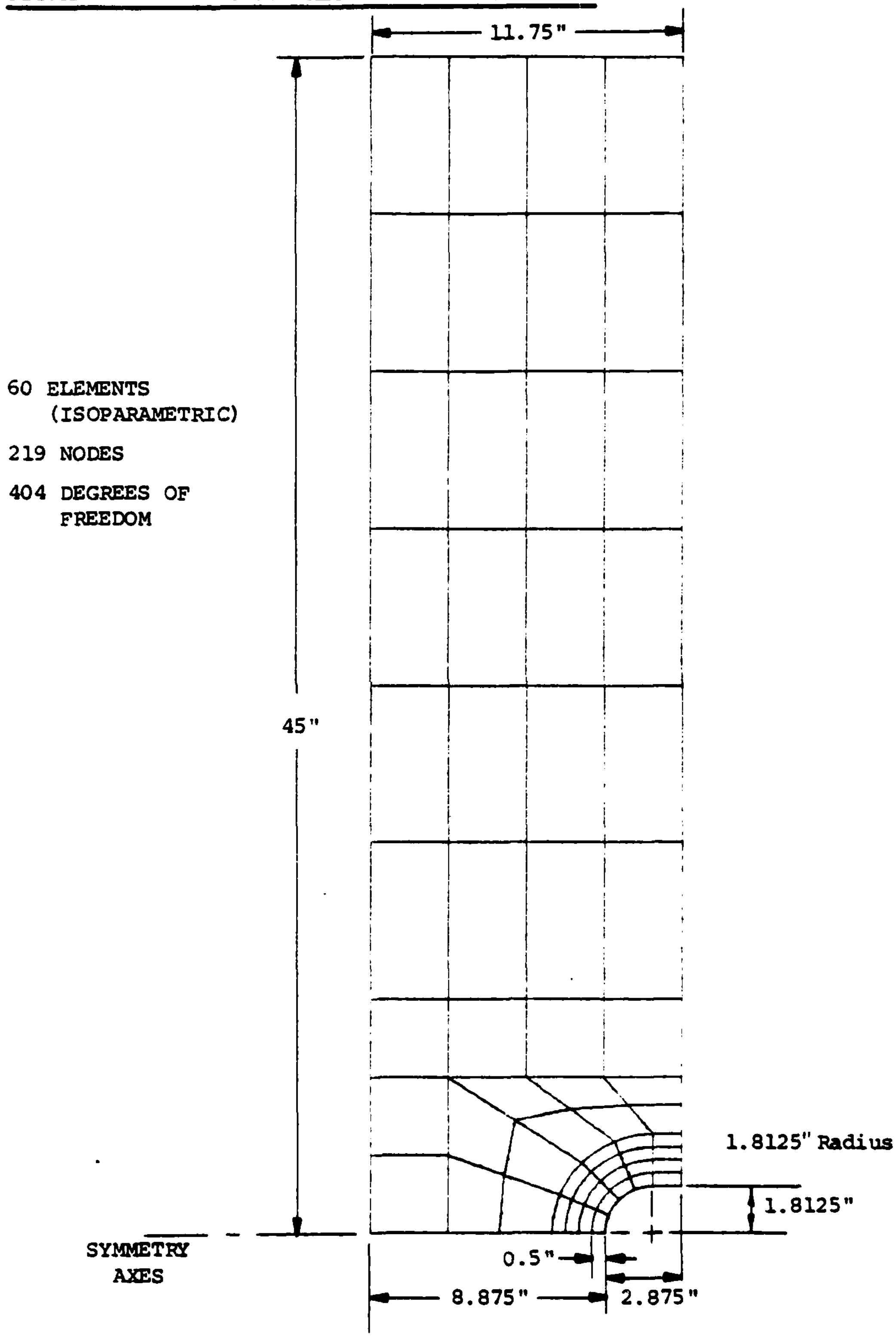


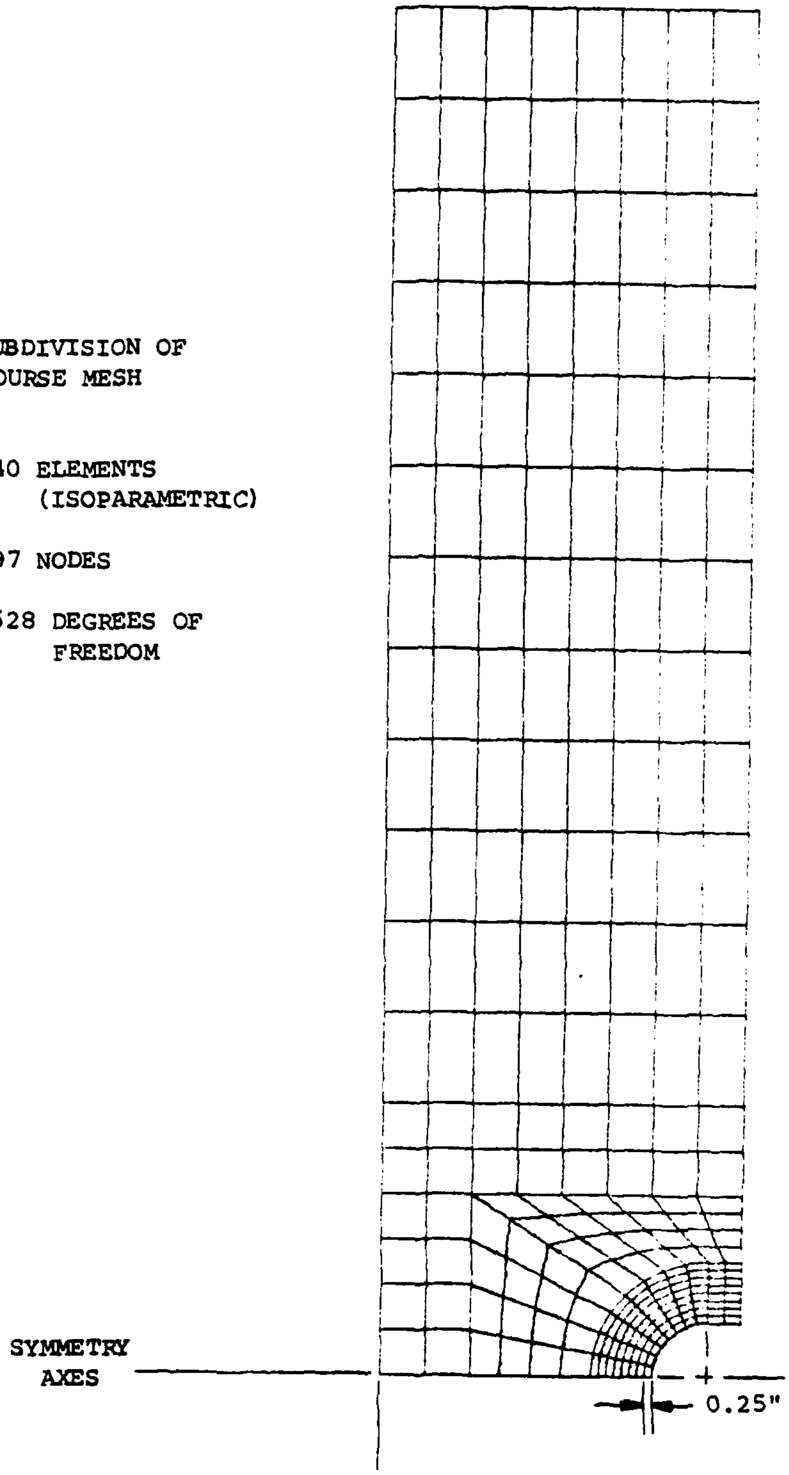
FIGURE 10 FINE MESH FOR SHALLOW NOTCH

SUBDIVISION OF
COURSE MESH

240 ELEMENTS
(ISOPARAMETRIC)

797 NODES

1528 DEGREES OF
FREEDOM



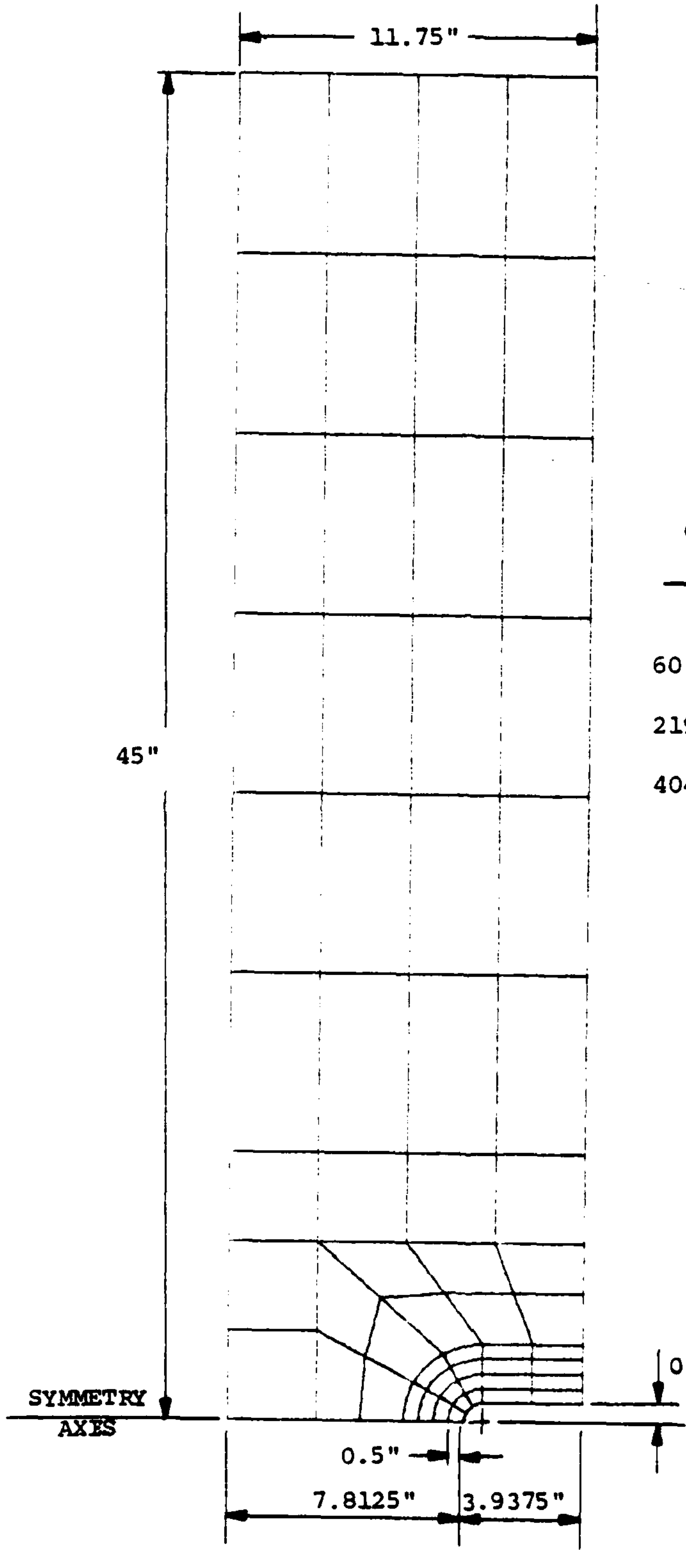


FIGURE 11

COURSE MESH FOR
DEEP NOTCH

60 ELEMENTS (ISOPARAMETRIC)

219 NODES

404 DEGREES OF FREEDOM

RADIUS OF NOTCH= 0.625"

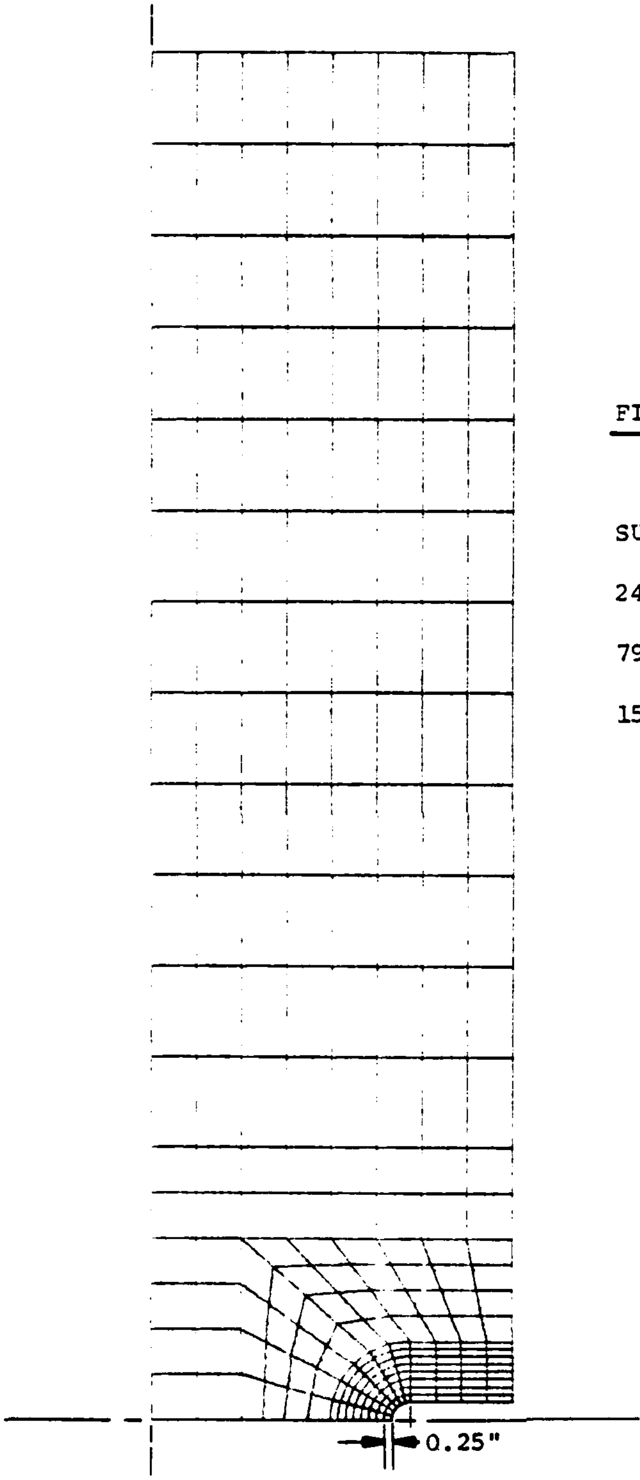


FIGURE 12

FINE MESH FOR DEEP NOTCH

SUBDIVISION OF COURSE MESH

240 ELEMENTS (ISOPARAMETRIC)

797 NODES

1528 DEGREES OF FREEDOM

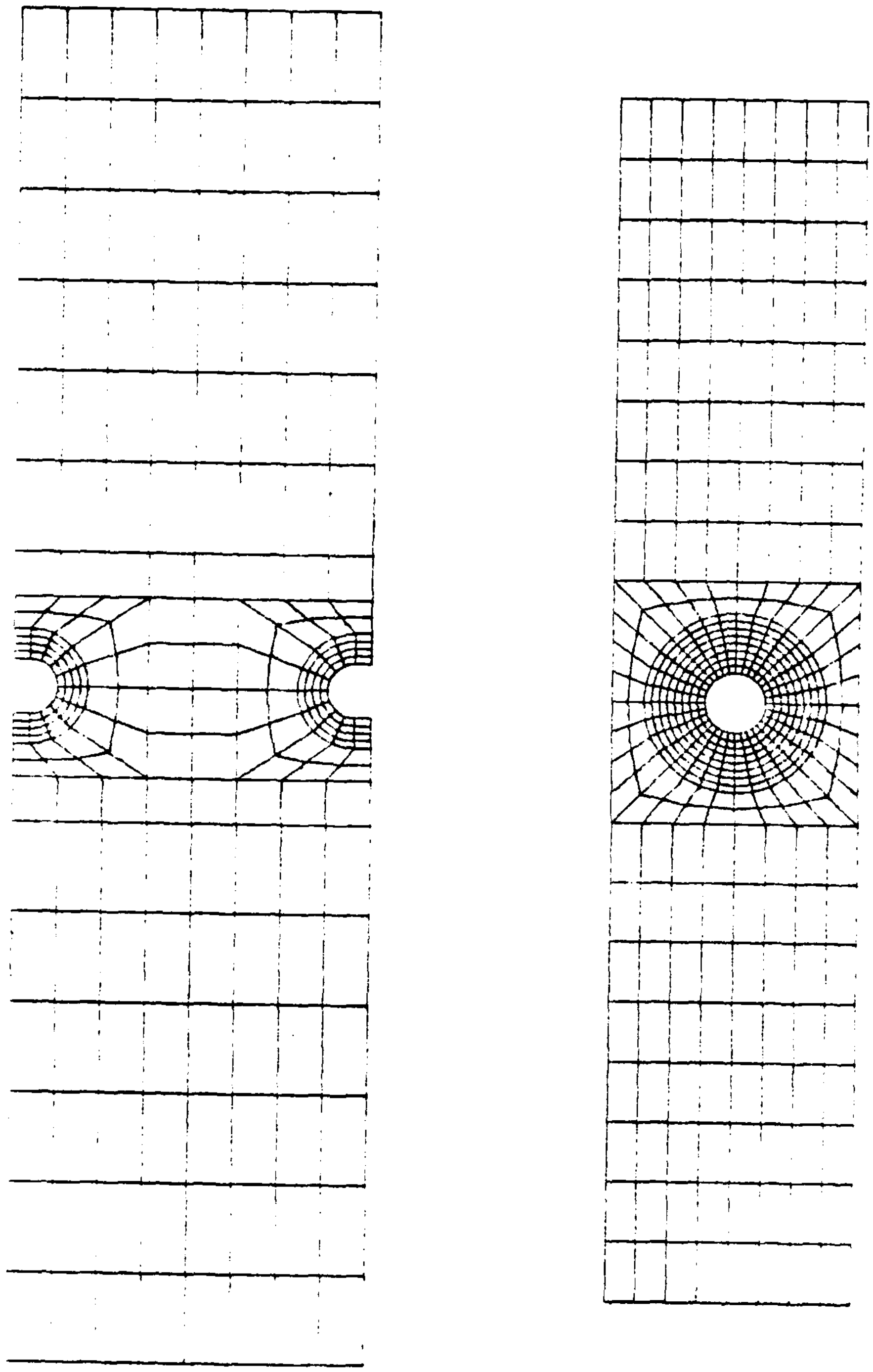


FIGURE 13

EXAMPLE OF COMPLETE PANEL MESHES

FIGURE 14 COMPUTATIONAL FLOW CHART

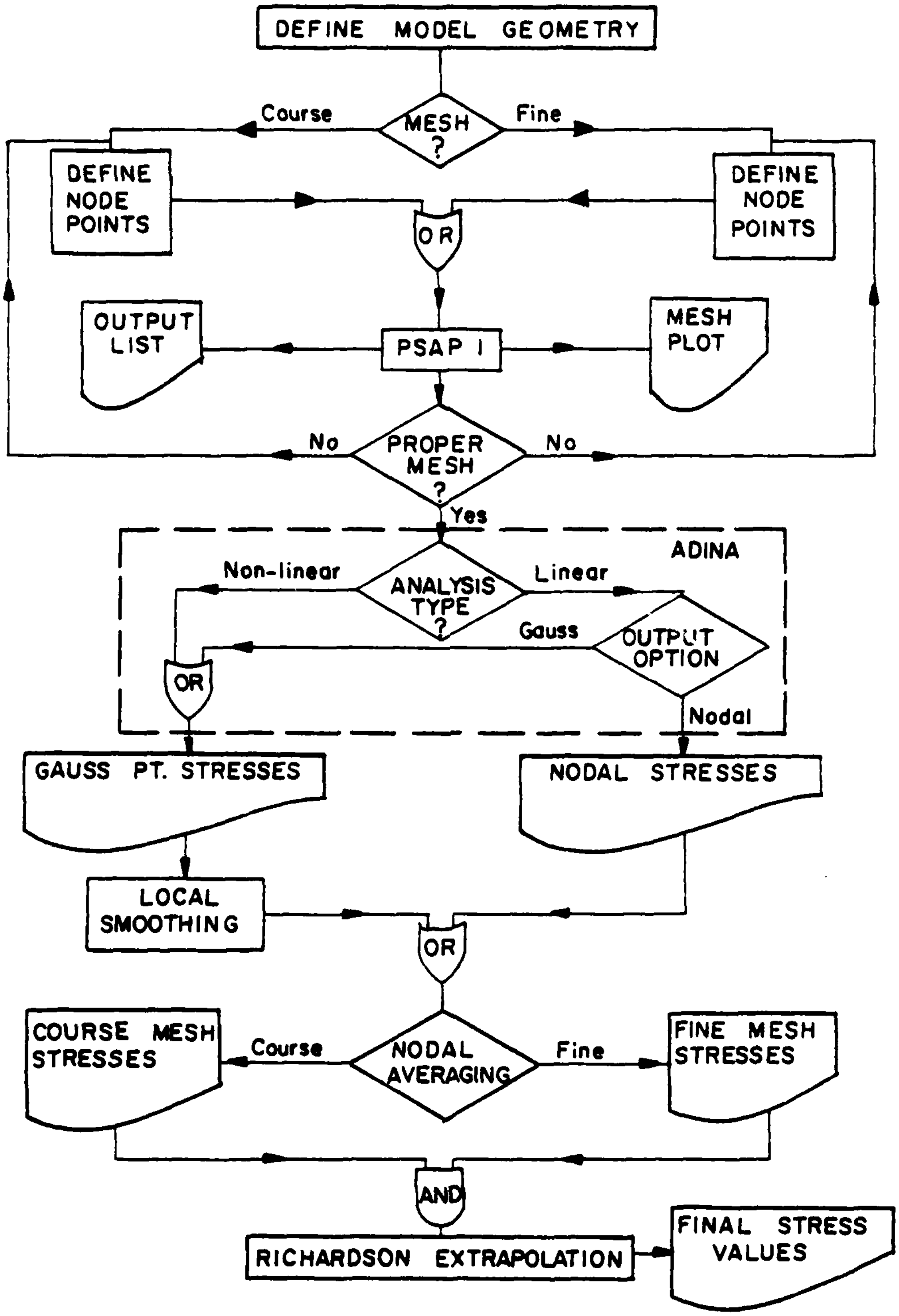


FIGURE 15

CIRCULAR HOLE λ=0.2 LINEAR RESULTS

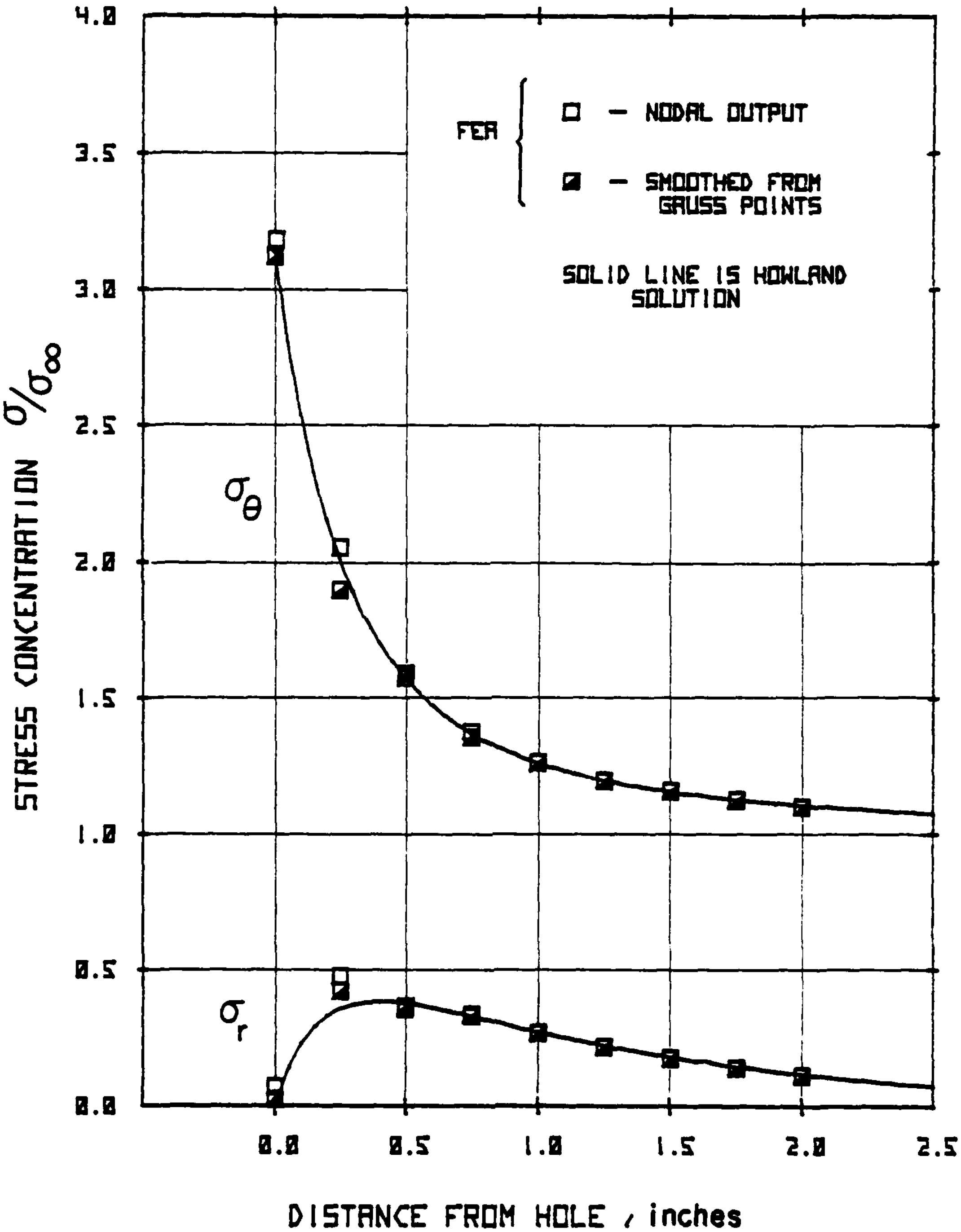


FIGURE 16

CIRCULAR HOLE λ=0.25 LINEAR RESULTS

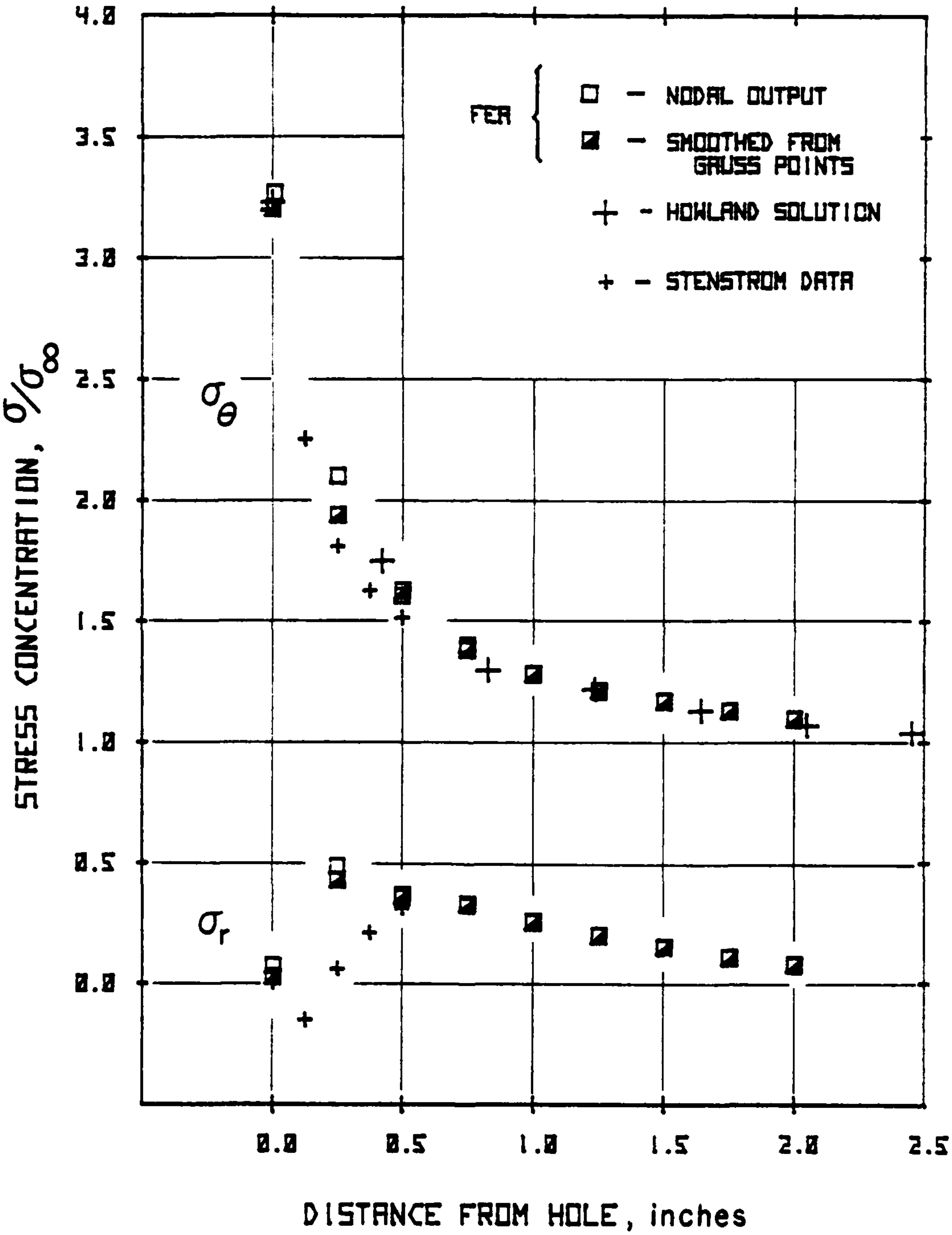


FIGURE 17

SHALLOW NOTCH LINEAR RESULTS

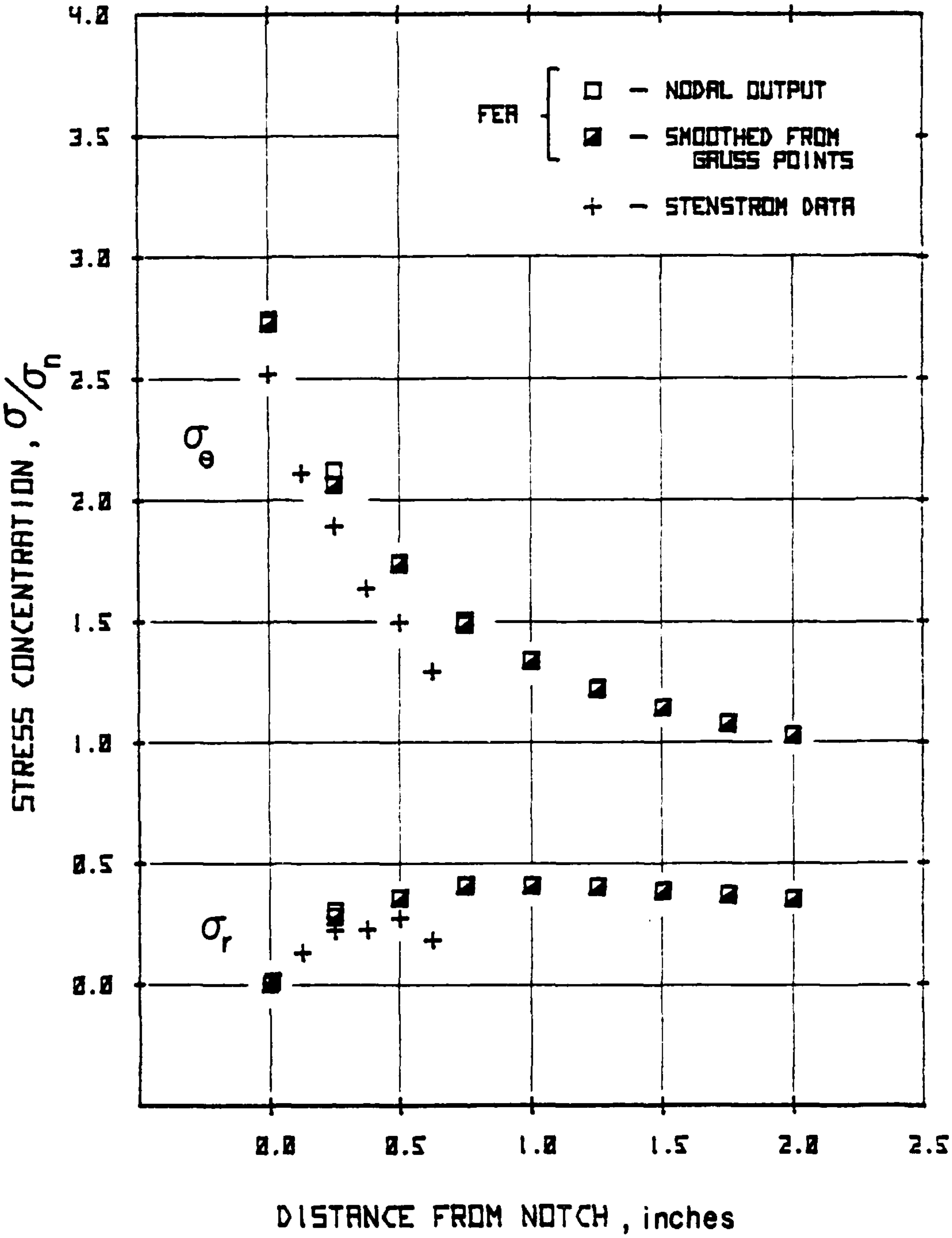


FIGURE 18

DEEP NOTCH LINEAR RESULTS

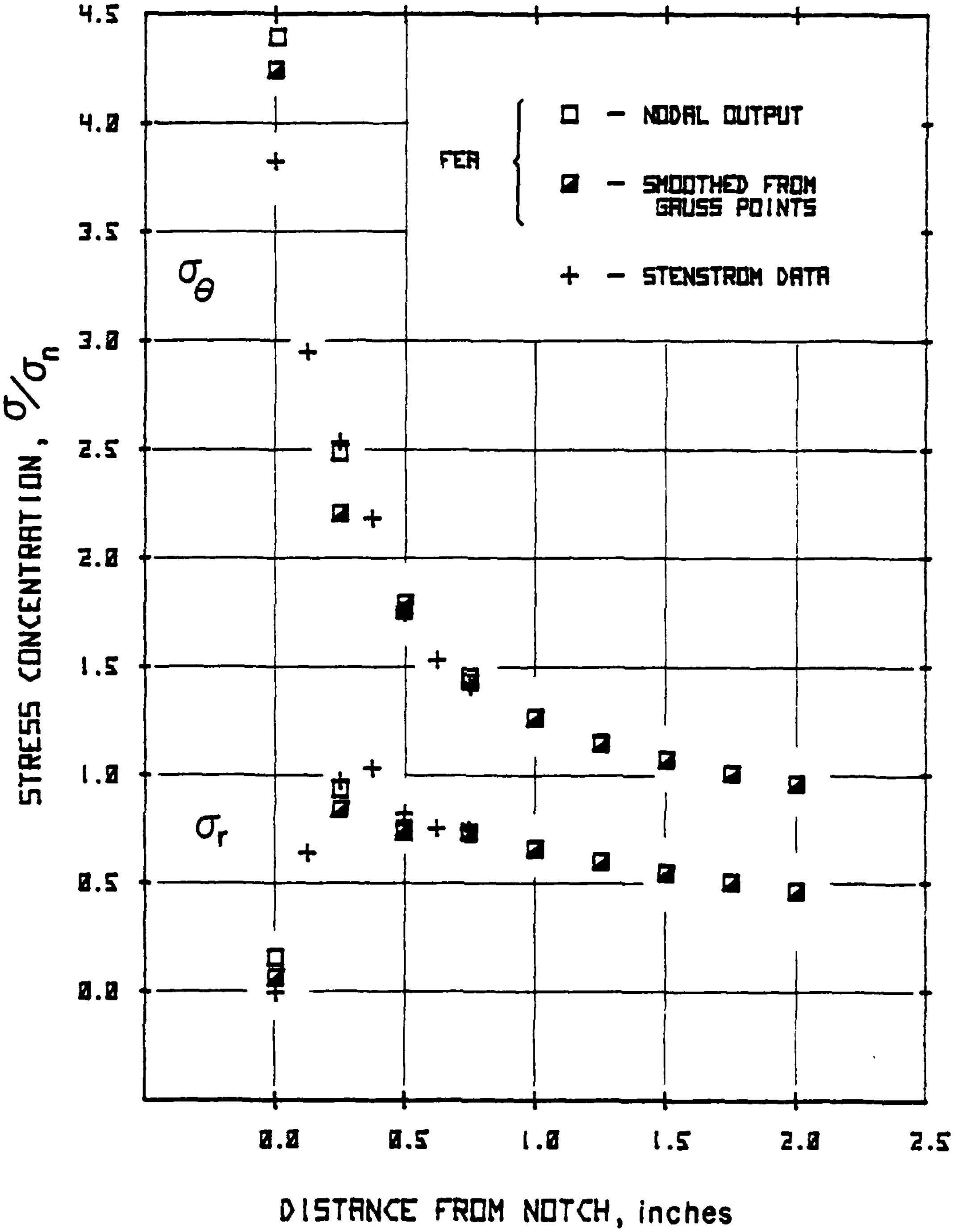


FIGURE 19

SHALLOW NOTCH 60000LB LOAD ELASTIC-PLASTIC RESULTS

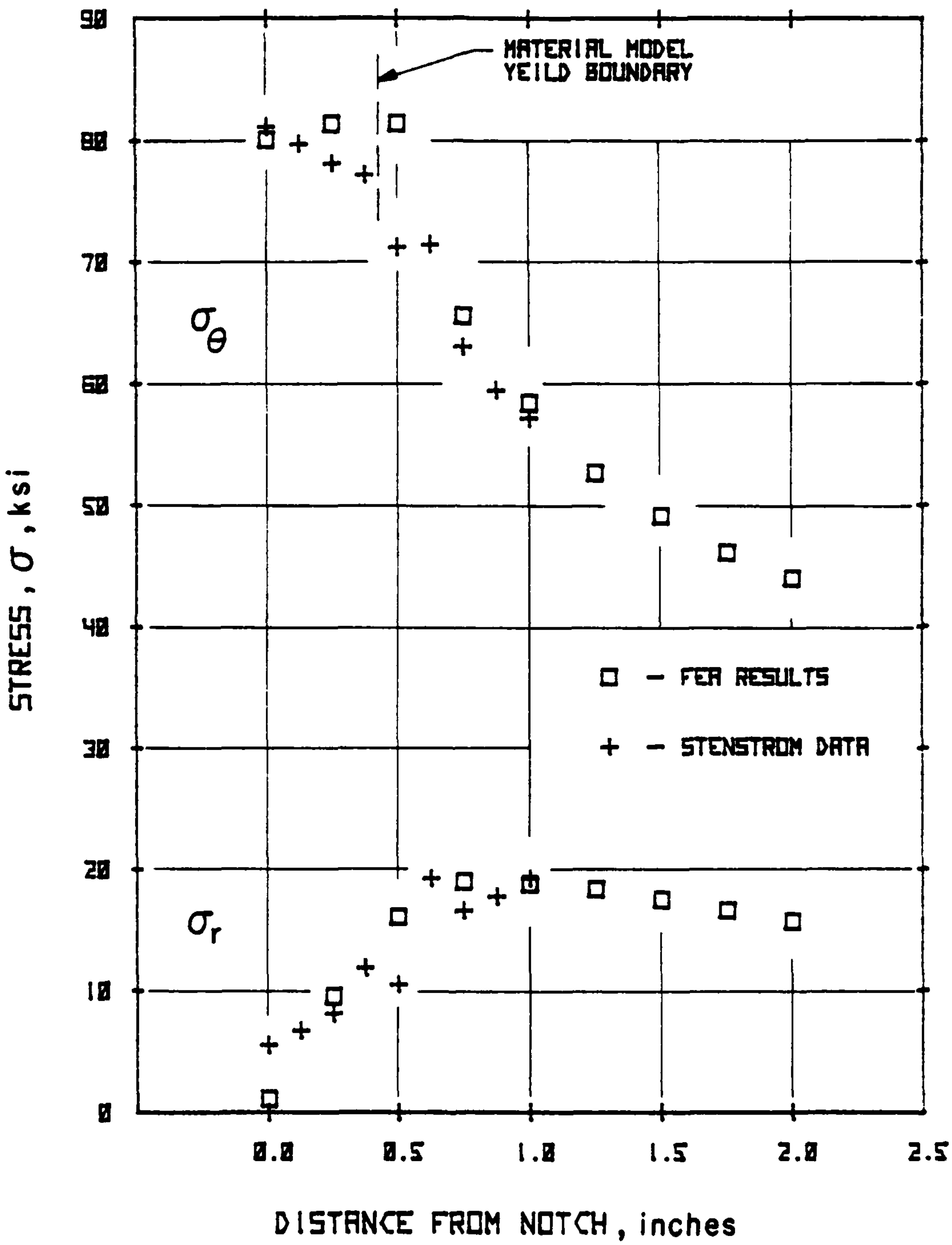


FIGURE 20

SHALLOW NOTCH 65000 LB LOAD ELASTIC-PLASTIC RESULTS

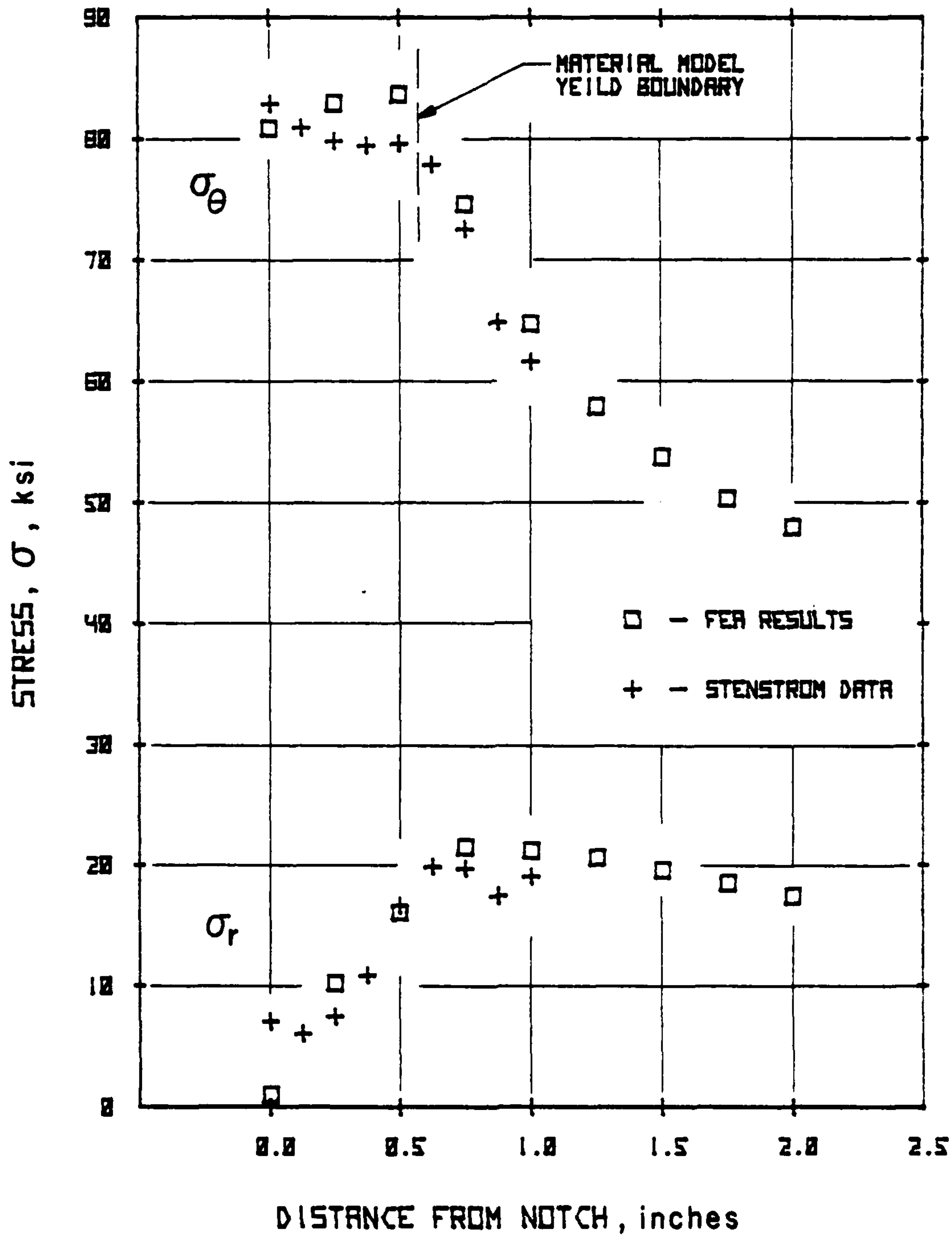
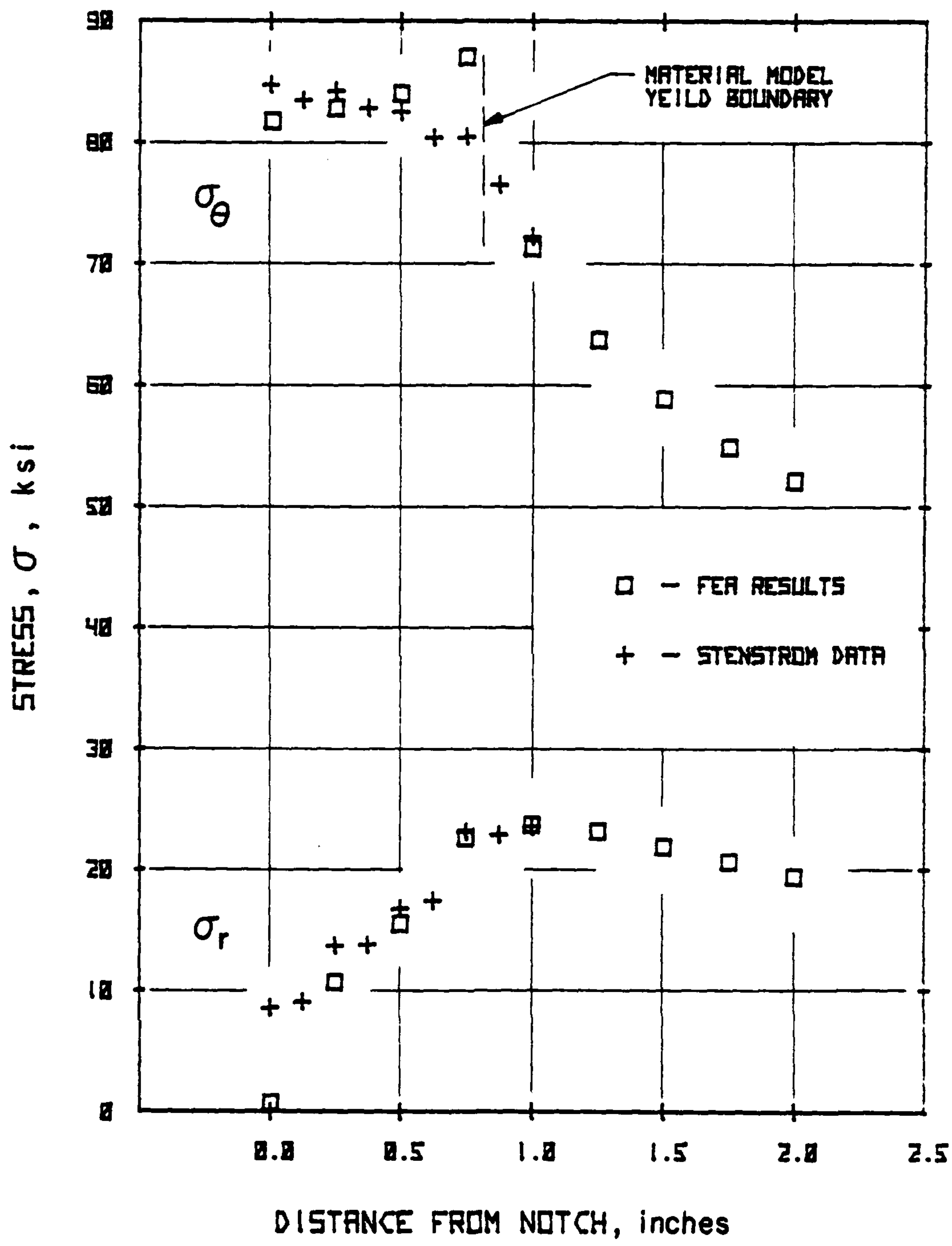


FIGURE 21

SHALLOW NOTCH 70000 LB LOAD ELASTIC-PLASTIC RESULTS



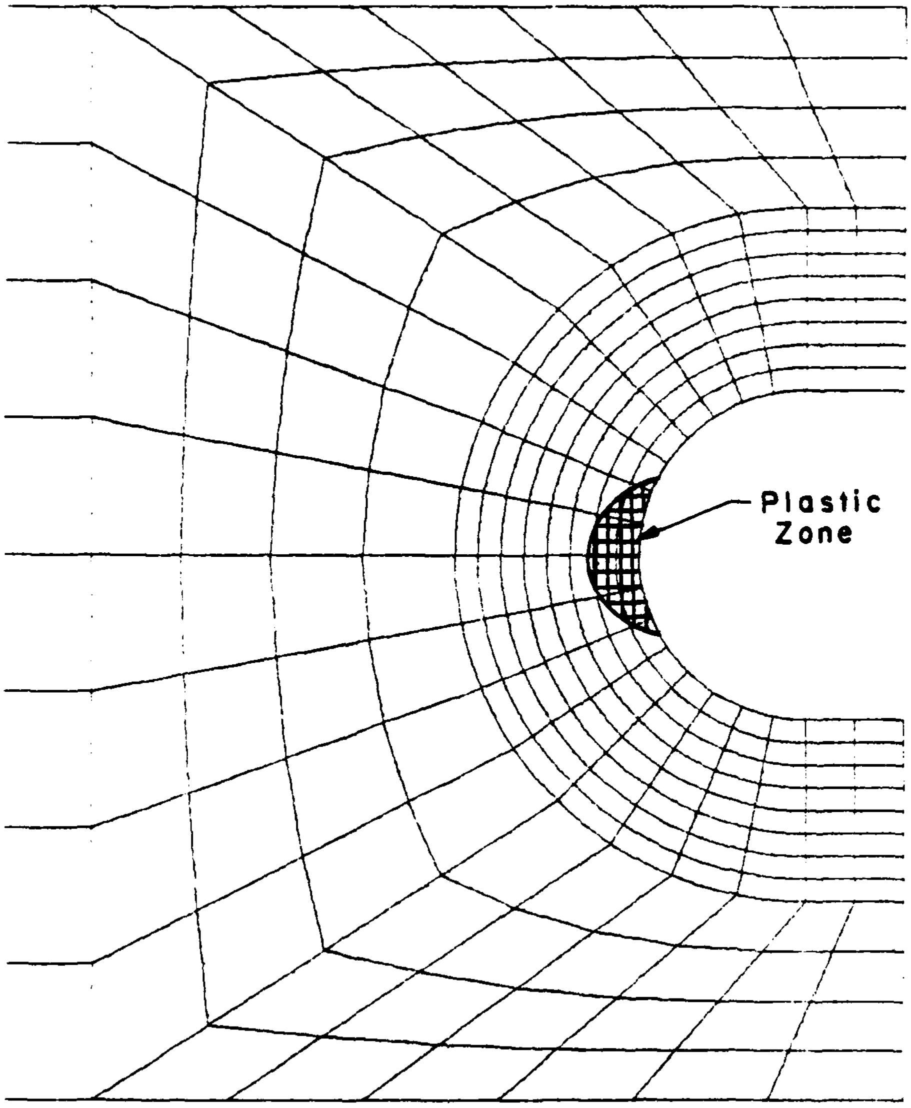


FIGURE 22

SHALLOW NOTCH 60,000 LB LOAD PLASTIC ZONE

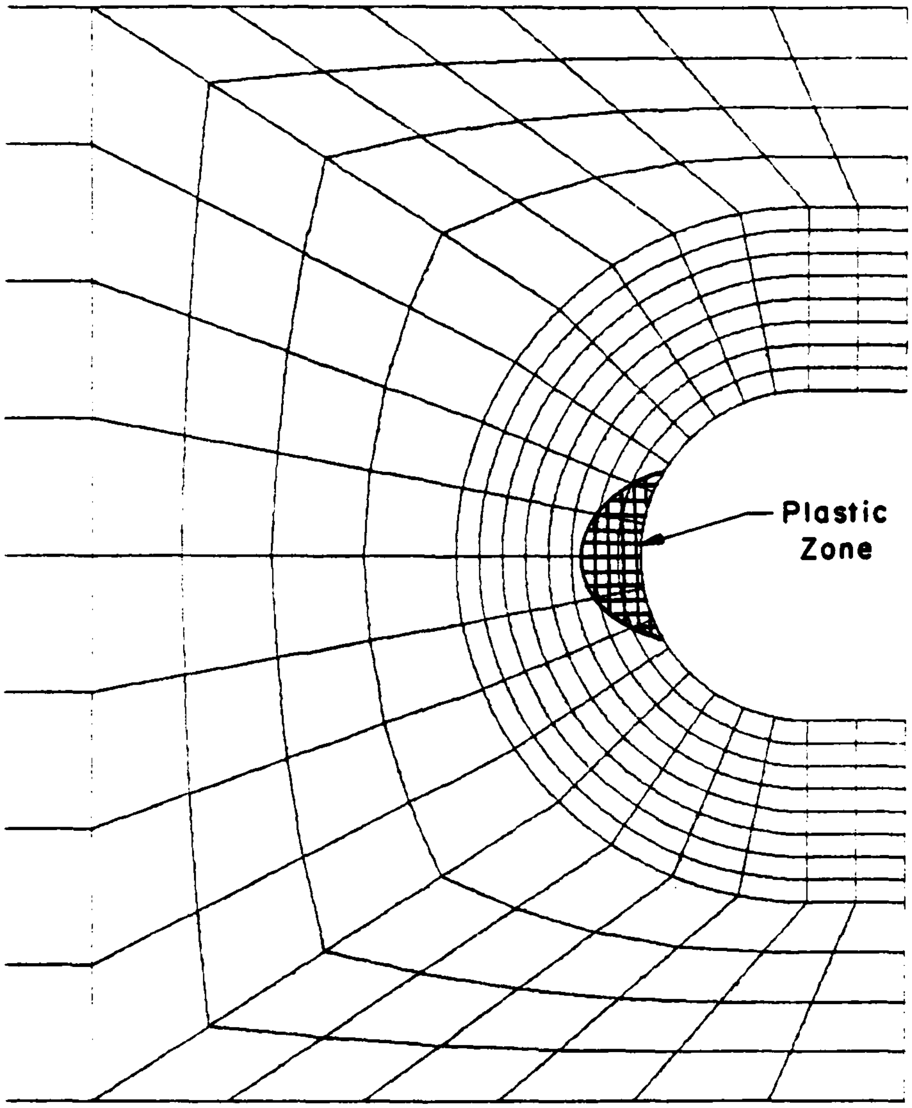


FIGURE 23

SHALLOW NOTCH 65,000 LB LOAD PLASTIC ZONE

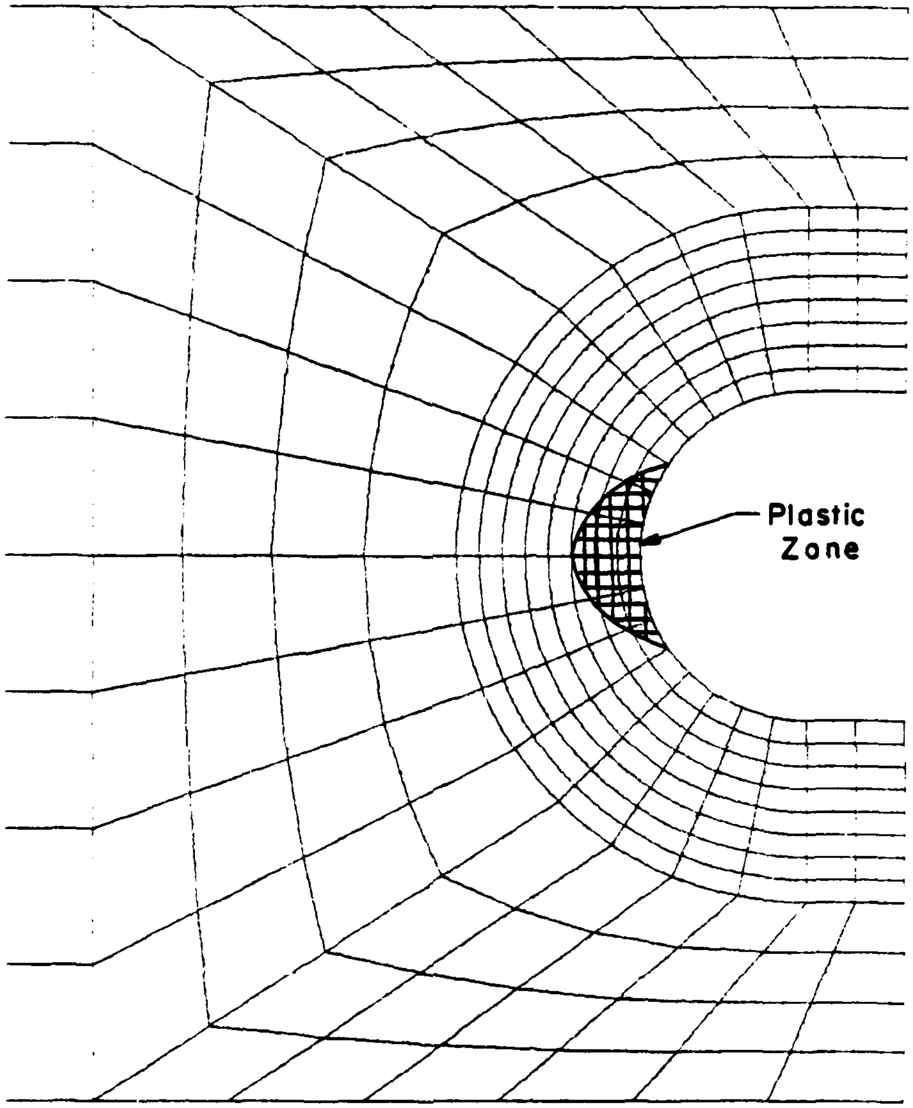


FIGURE 24

SHALLOW NOTCH 70,000 LB LOAD PLASTIC ZONE

FIGURE 25

SHALLOW NOTCH RESIDUAL σ_θ FROM 60,000 LB LOAD

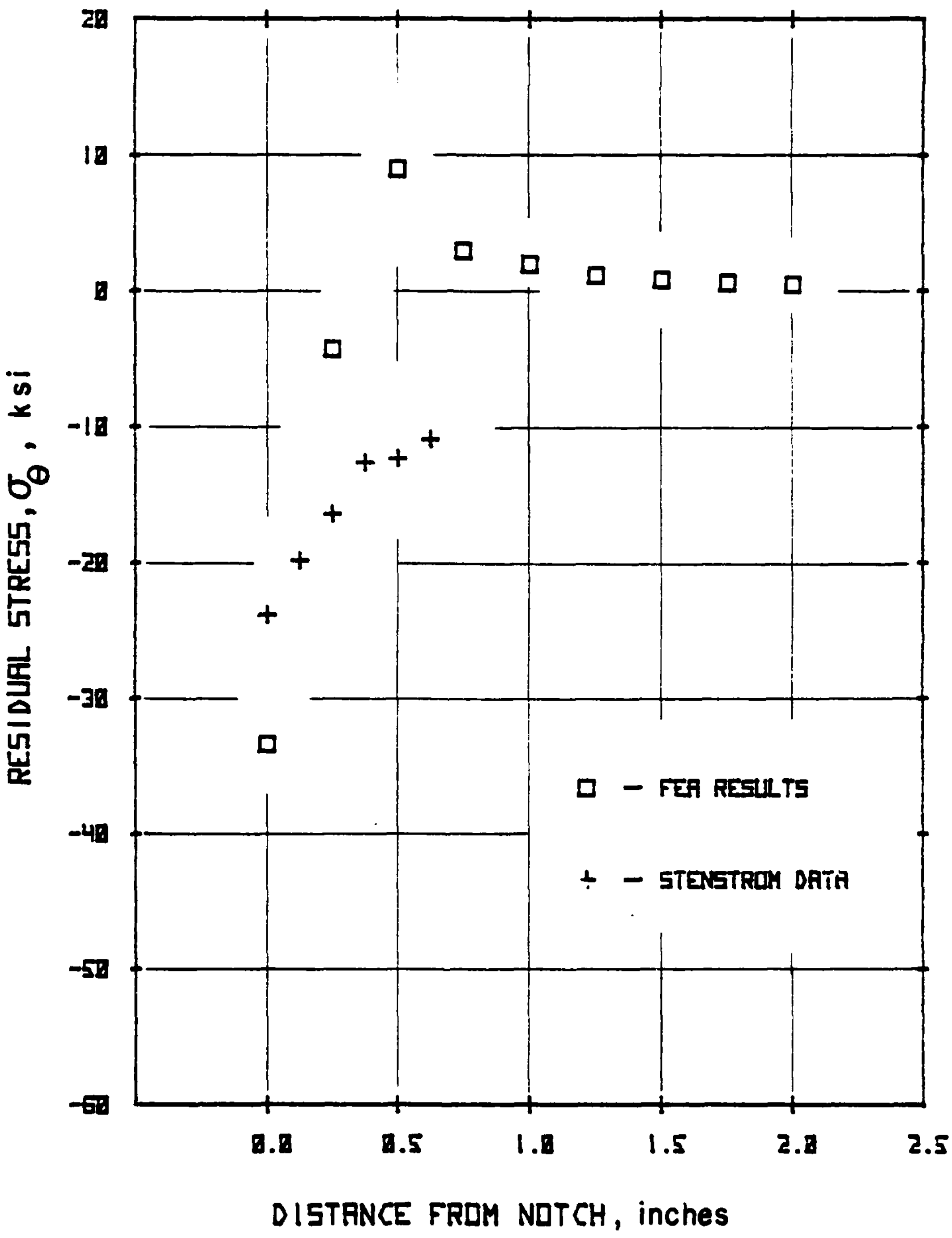


FIGURE 26

SHALLOW NOTCH RESIDUAL σ_r FROM 60,000 LB LOAD

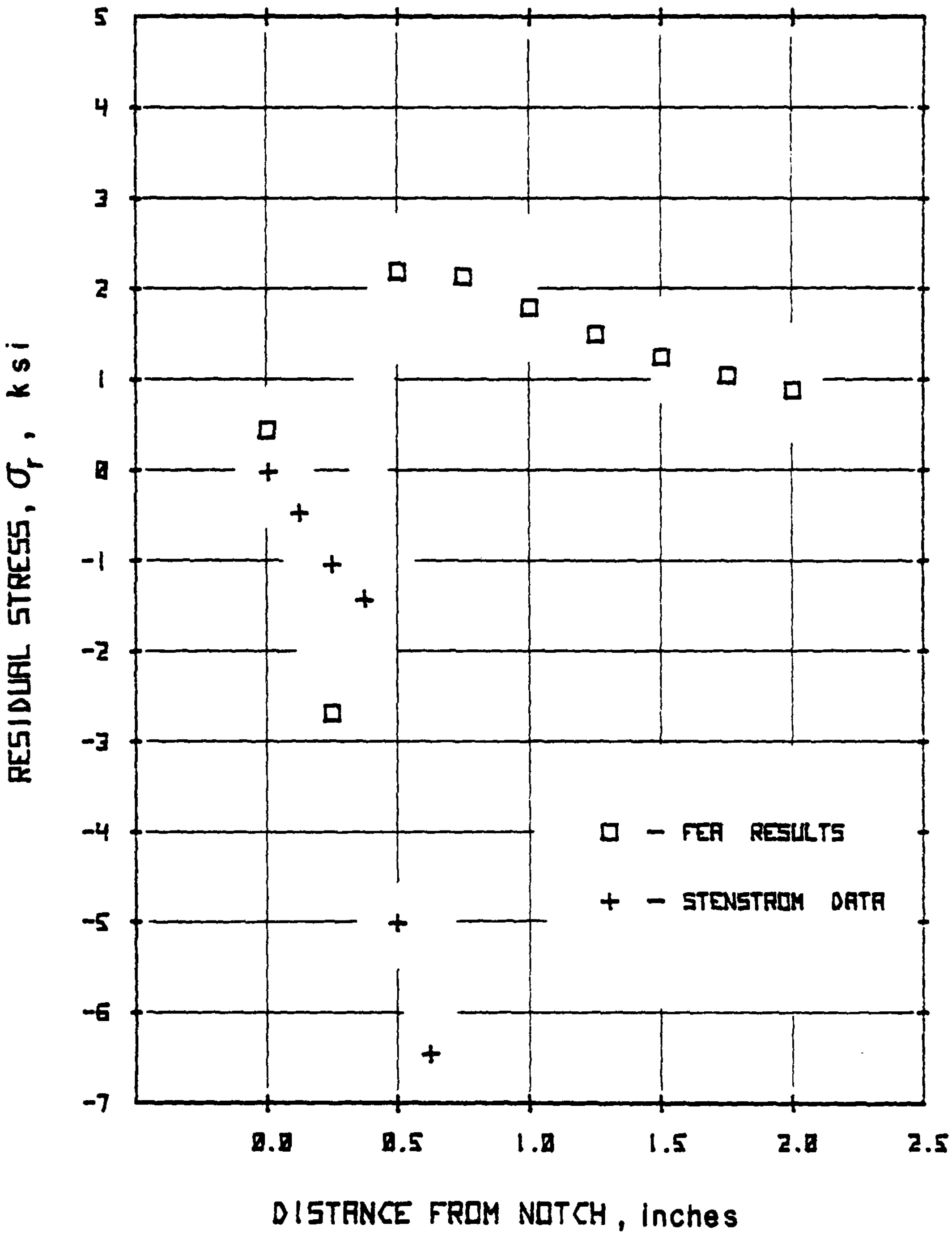


FIGURE 27

SHALLOW NOTCH RESIDUAL σ_θ FROM 65,000 LB LOAD

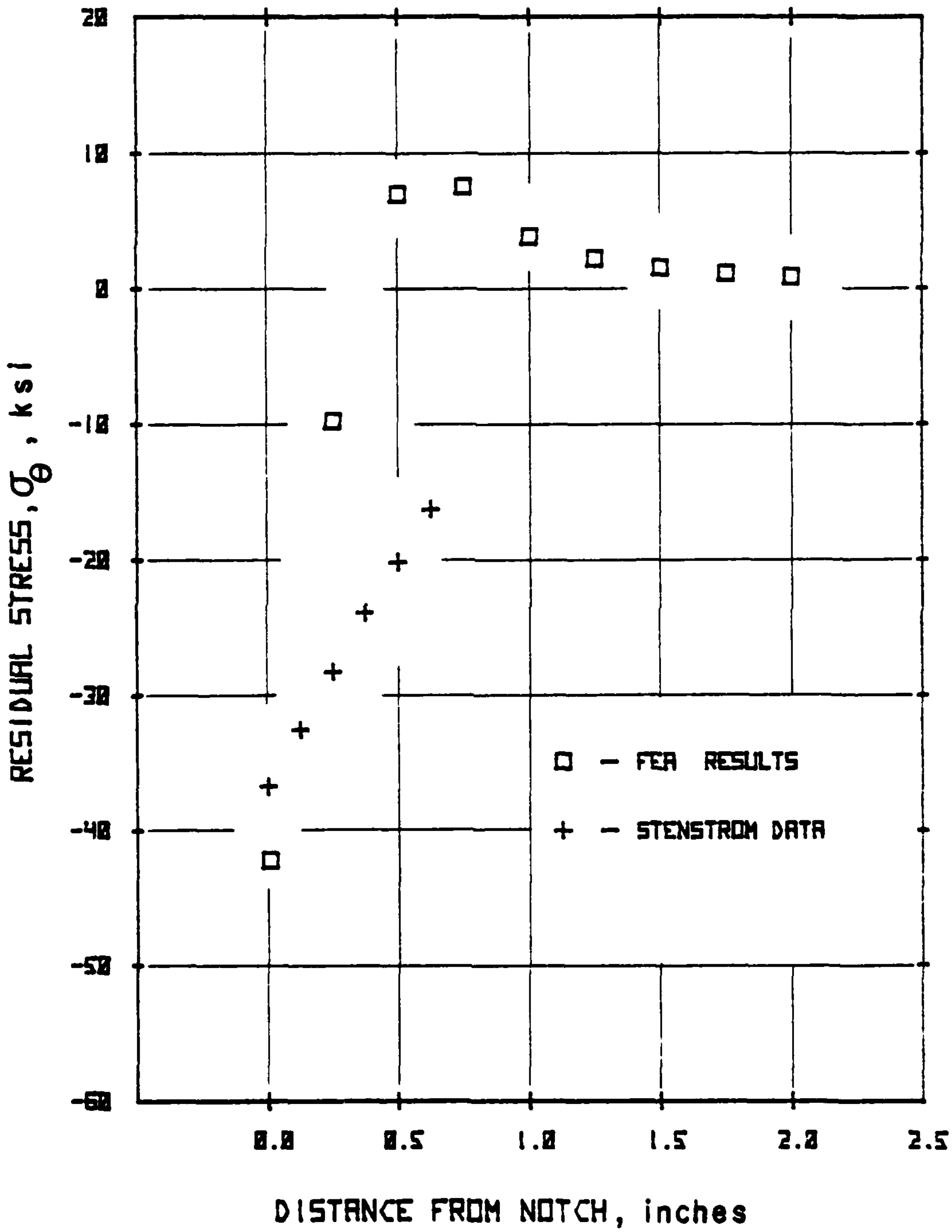


FIGURE 28

SHALLOW NOTCH RESIDUAL σ_r FROM 65,000 LB LOAD

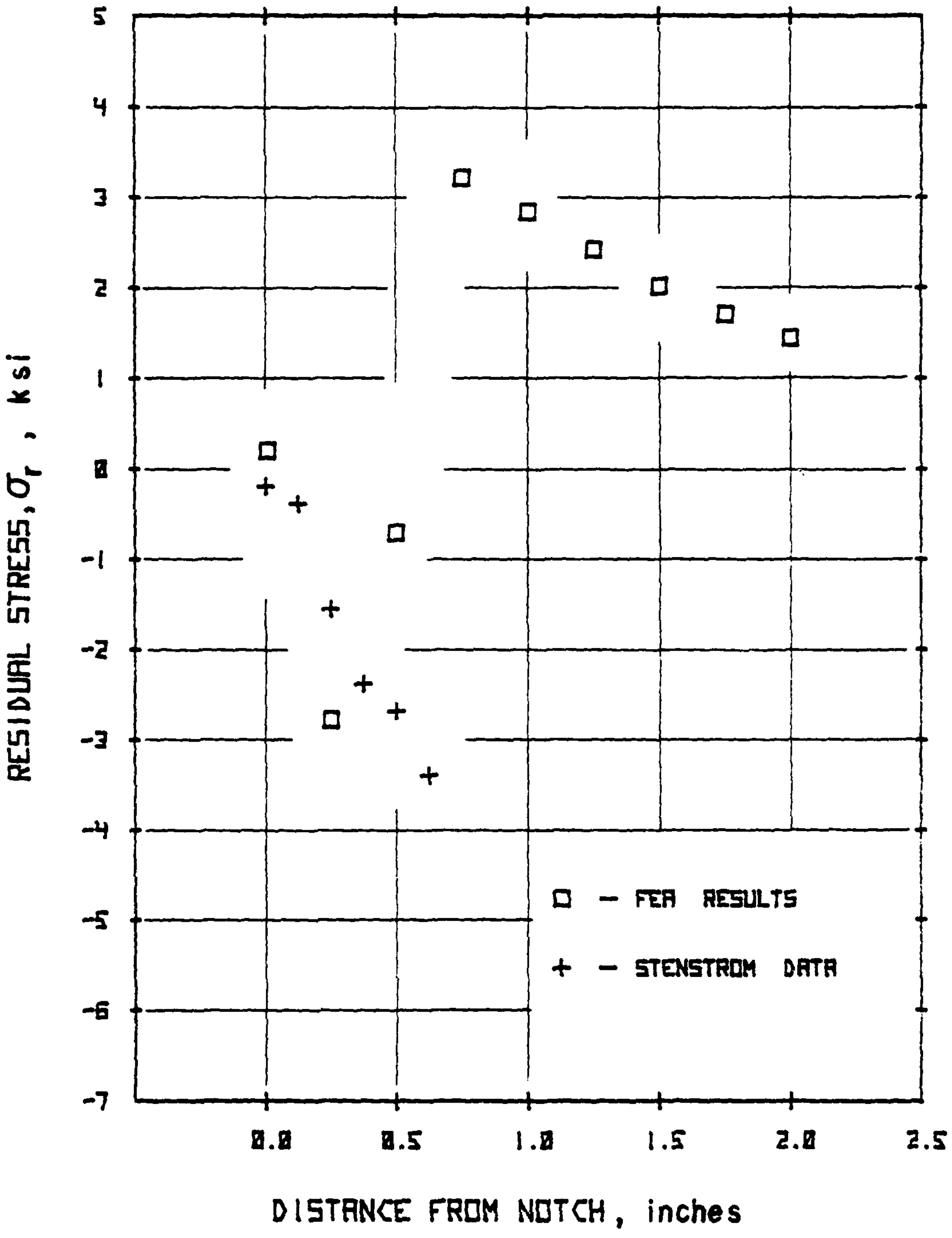


FIGURE 29

SHALLOW NOTCH RESIDUAL σ_θ FROM 70,000 LB LOAD

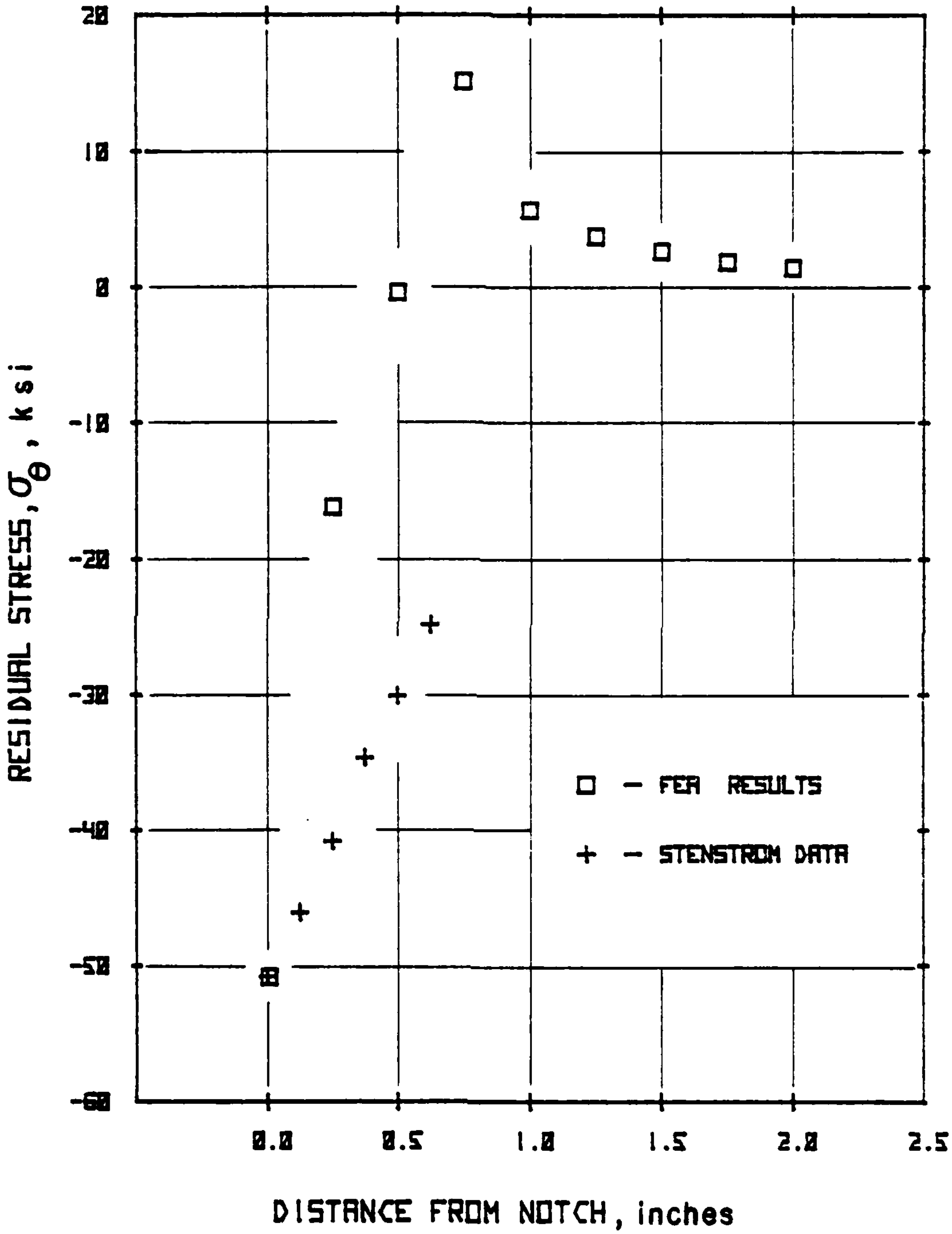


FIGURE 30

SHALLOW NOTCH RESIDUAL σ_r FROM 70,000 LB LOAD

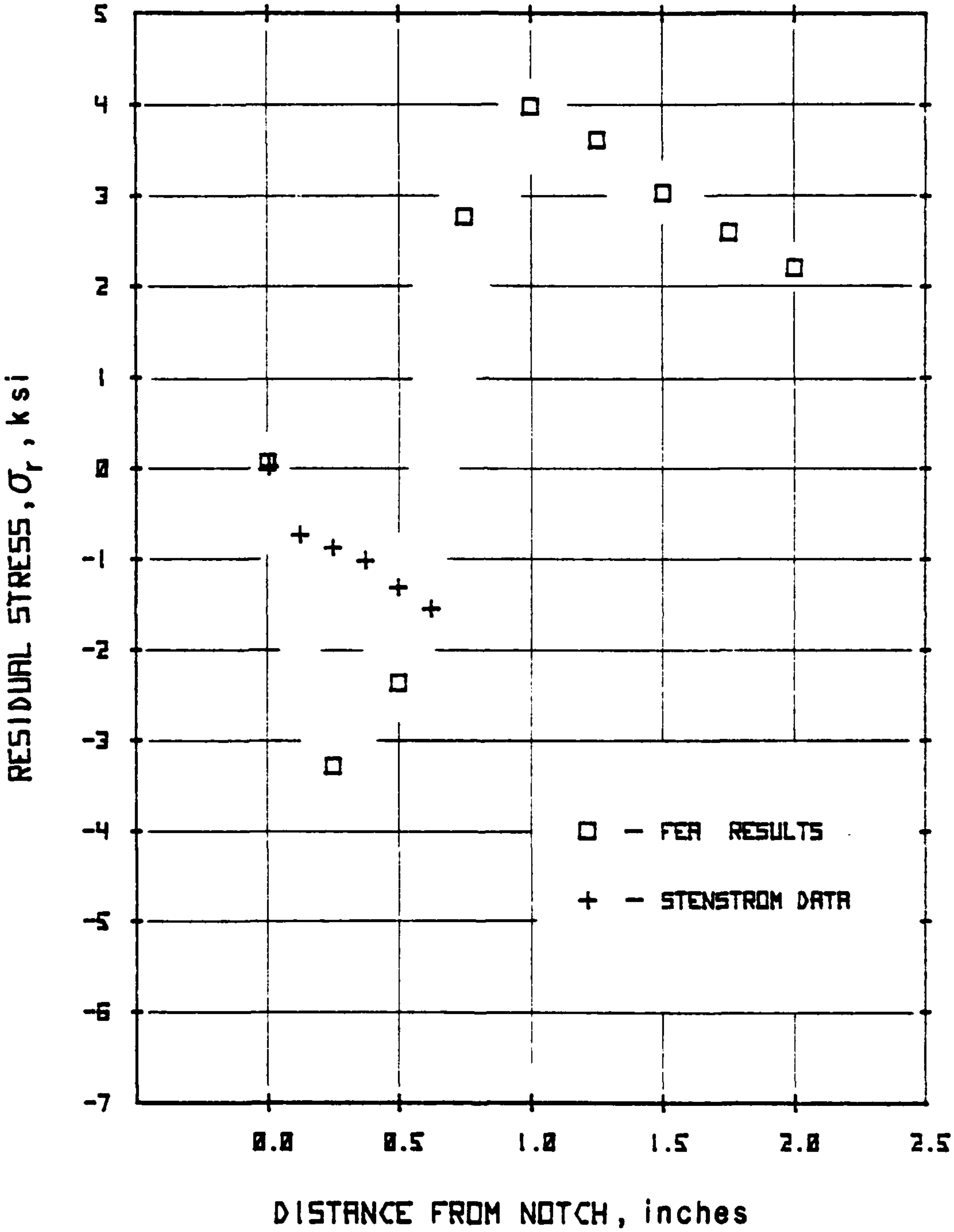


FIGURE 31

DEEP NOTCH PLASTIC LOADING RESULTS

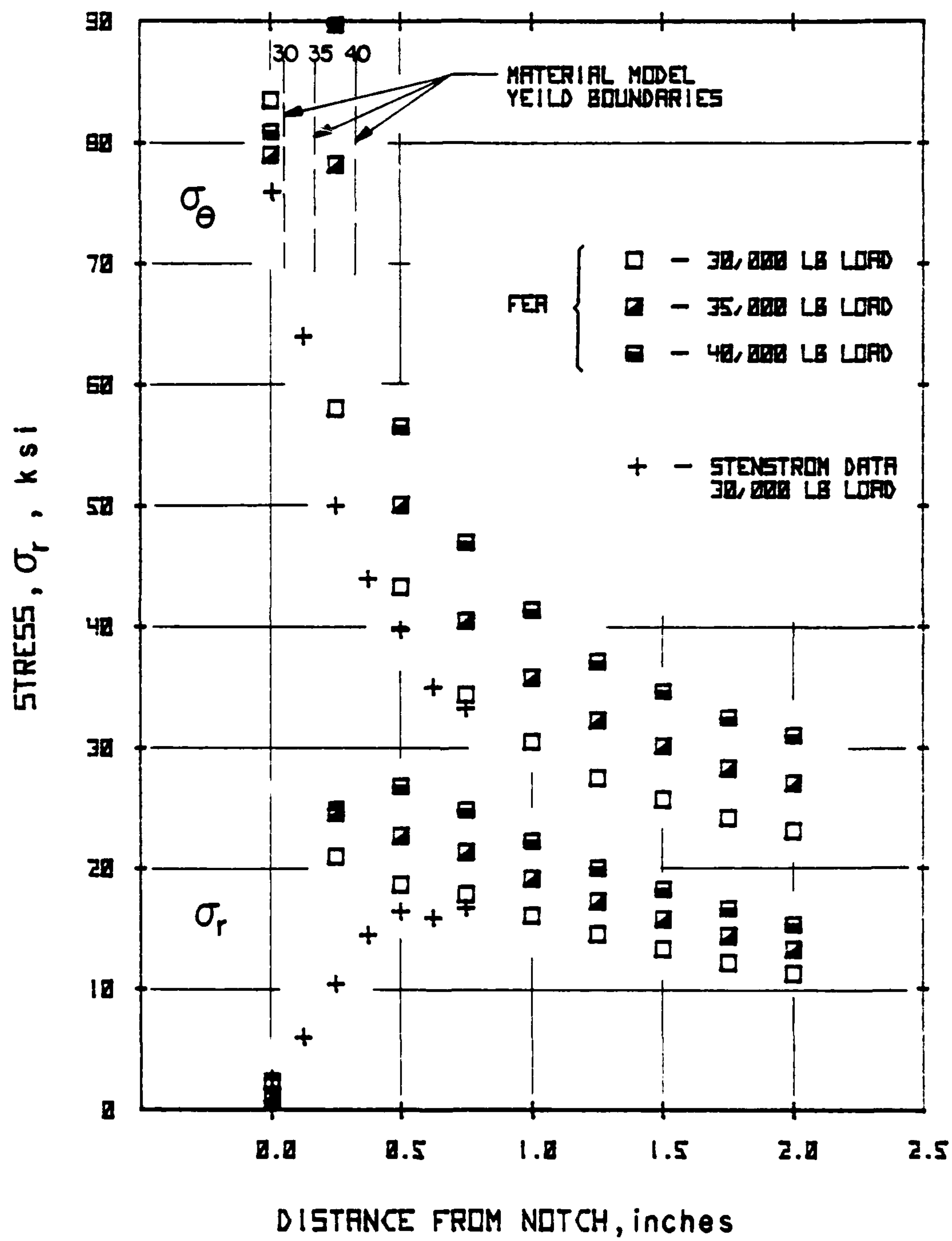


FIGURE 32

DEEP NOTCH σ_θ RESIDUALS

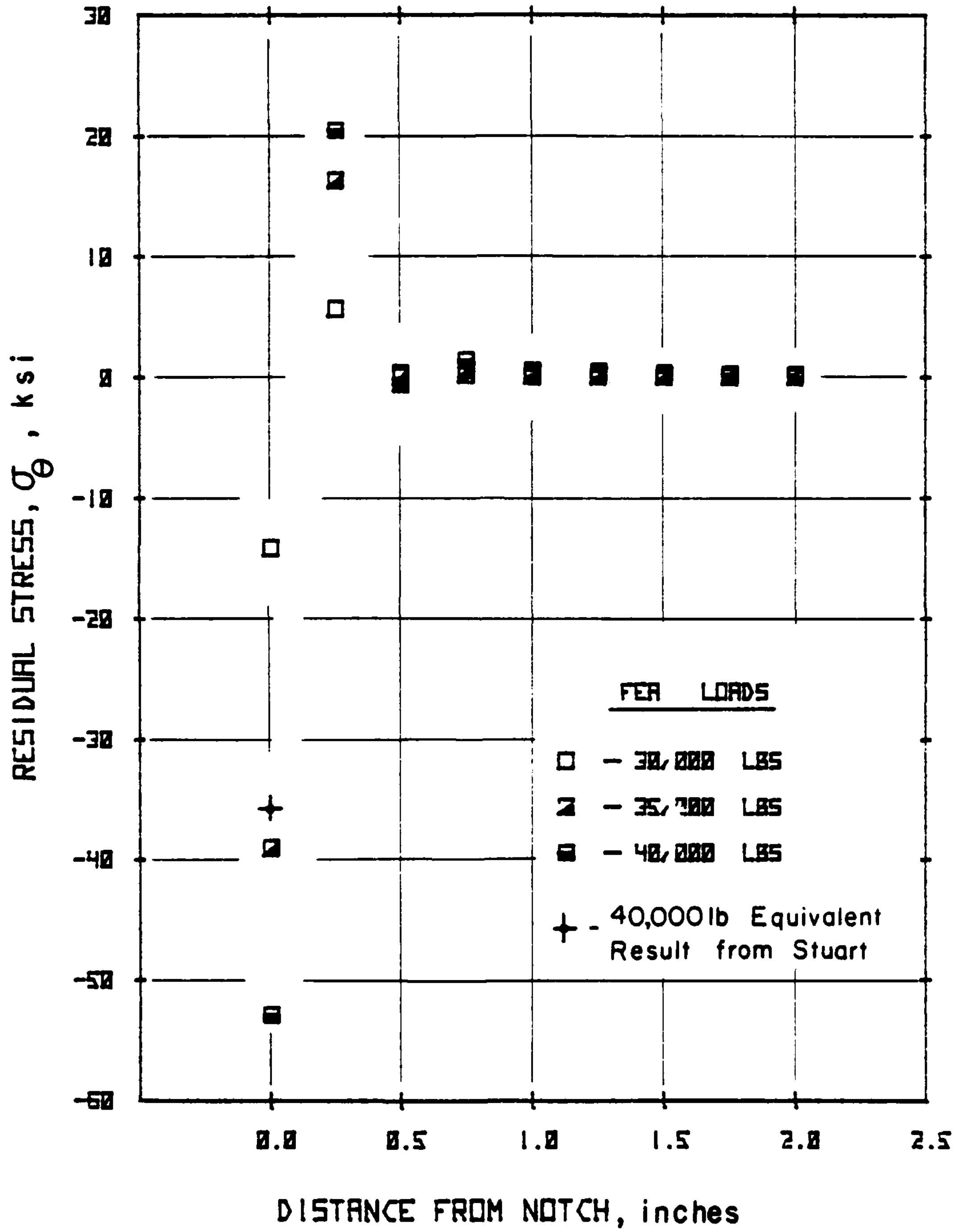
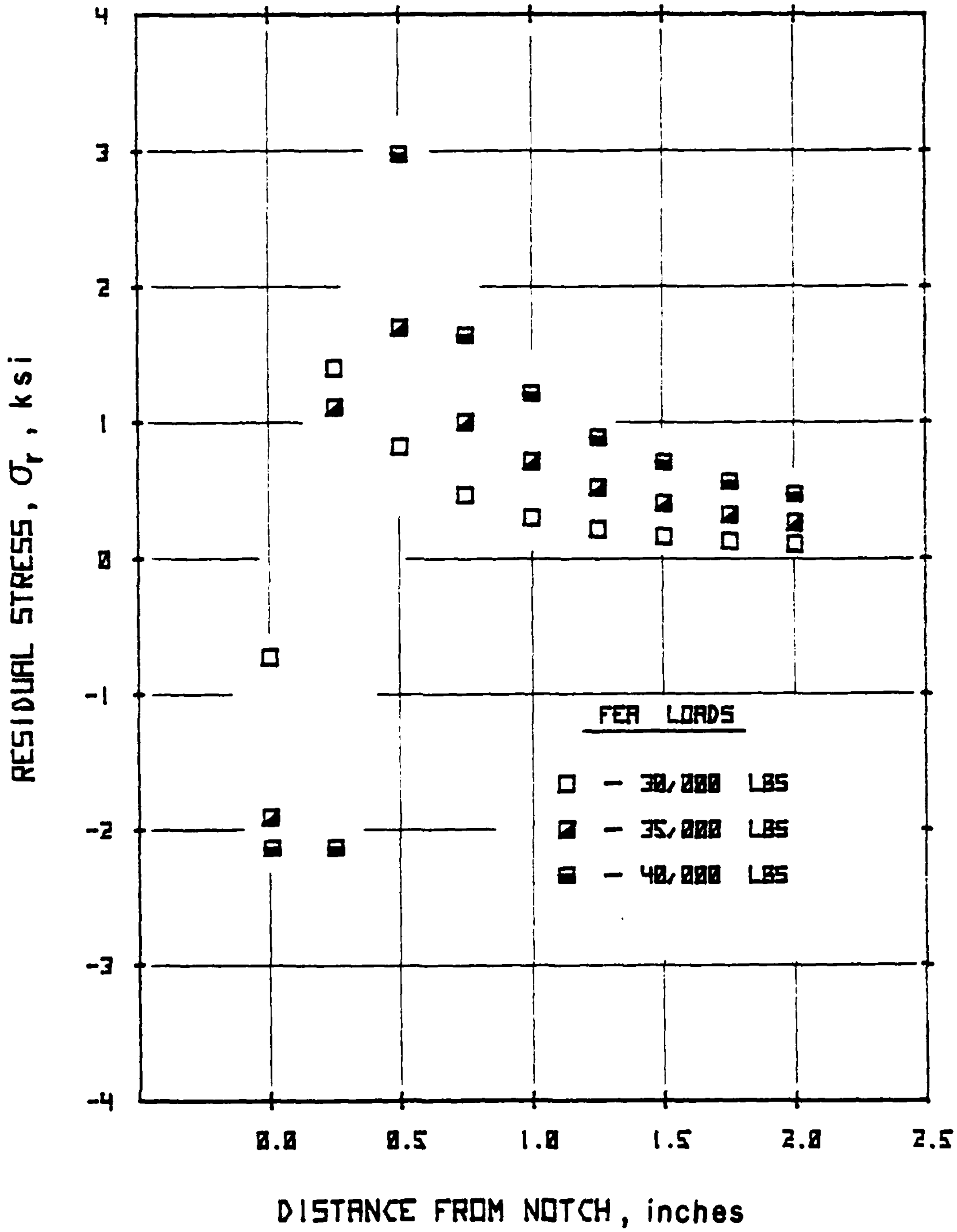


FIGURE 33

DEEP NOTCH σ_r RESIDUALS



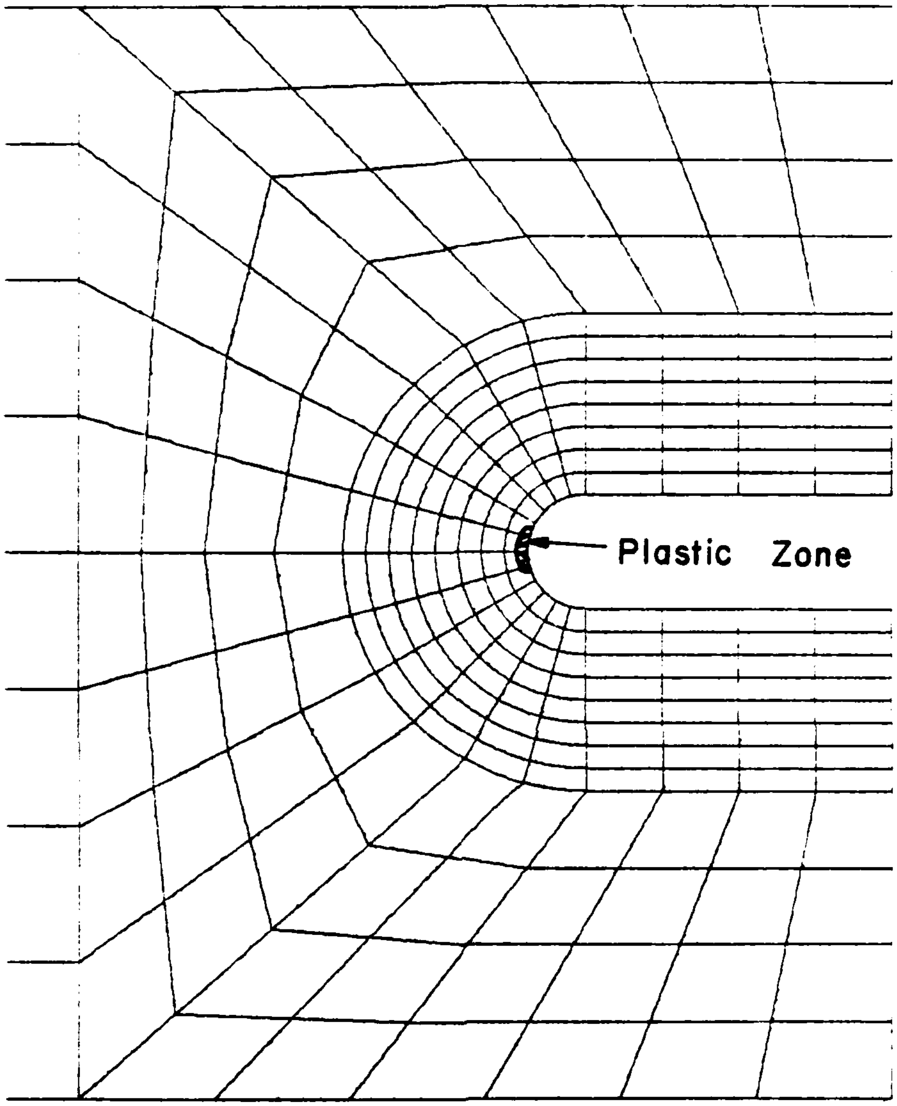


FIGURE 34

DEEP NOTCH 30,000 LB LOAD PLASTIC ZONE

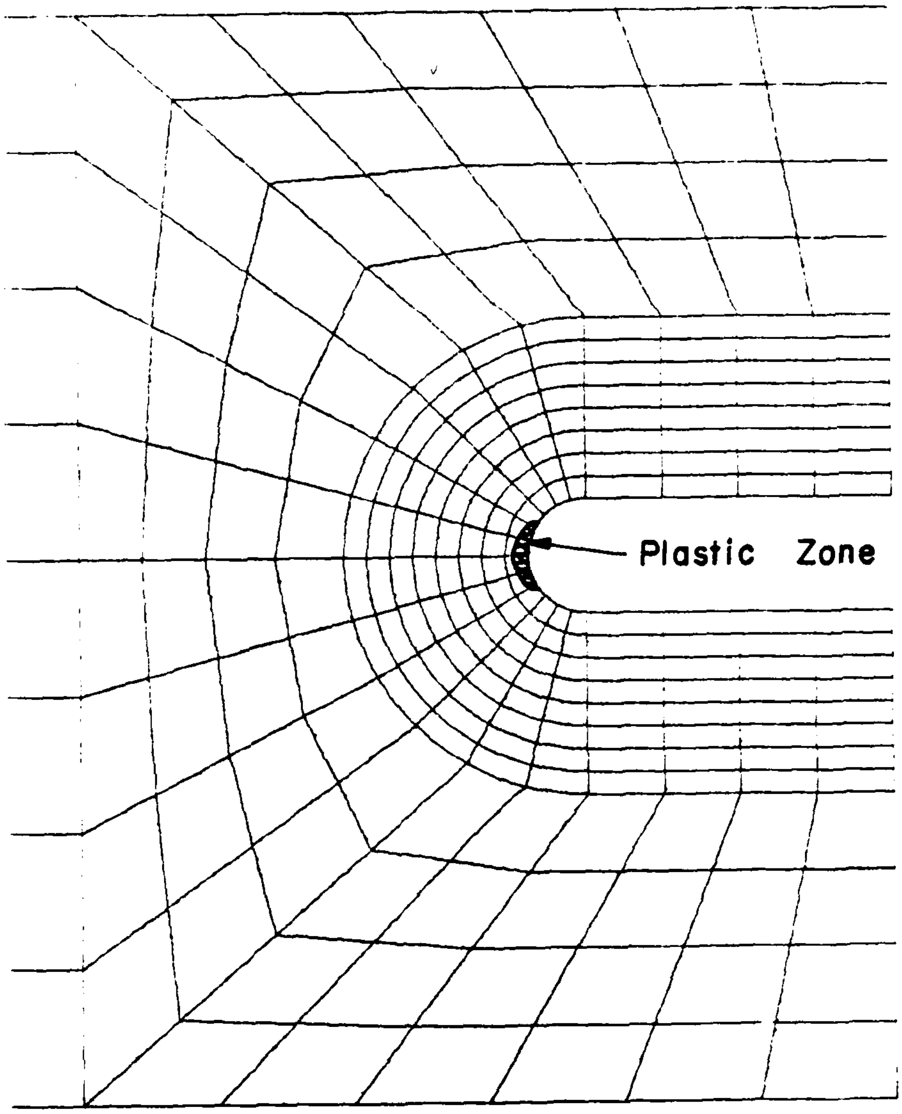


FIGURE 35

DEEP NOTCH 35,000 LB LOAD PLASTIC ZONE

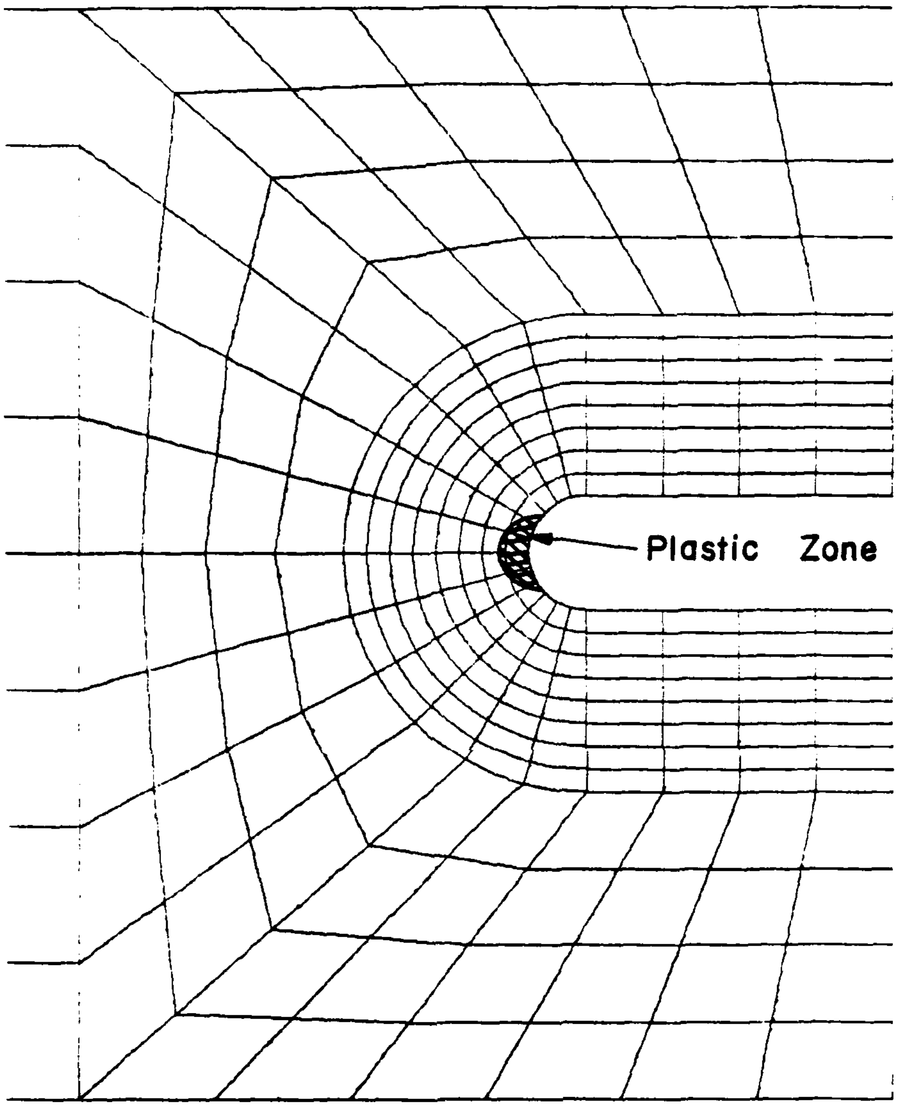
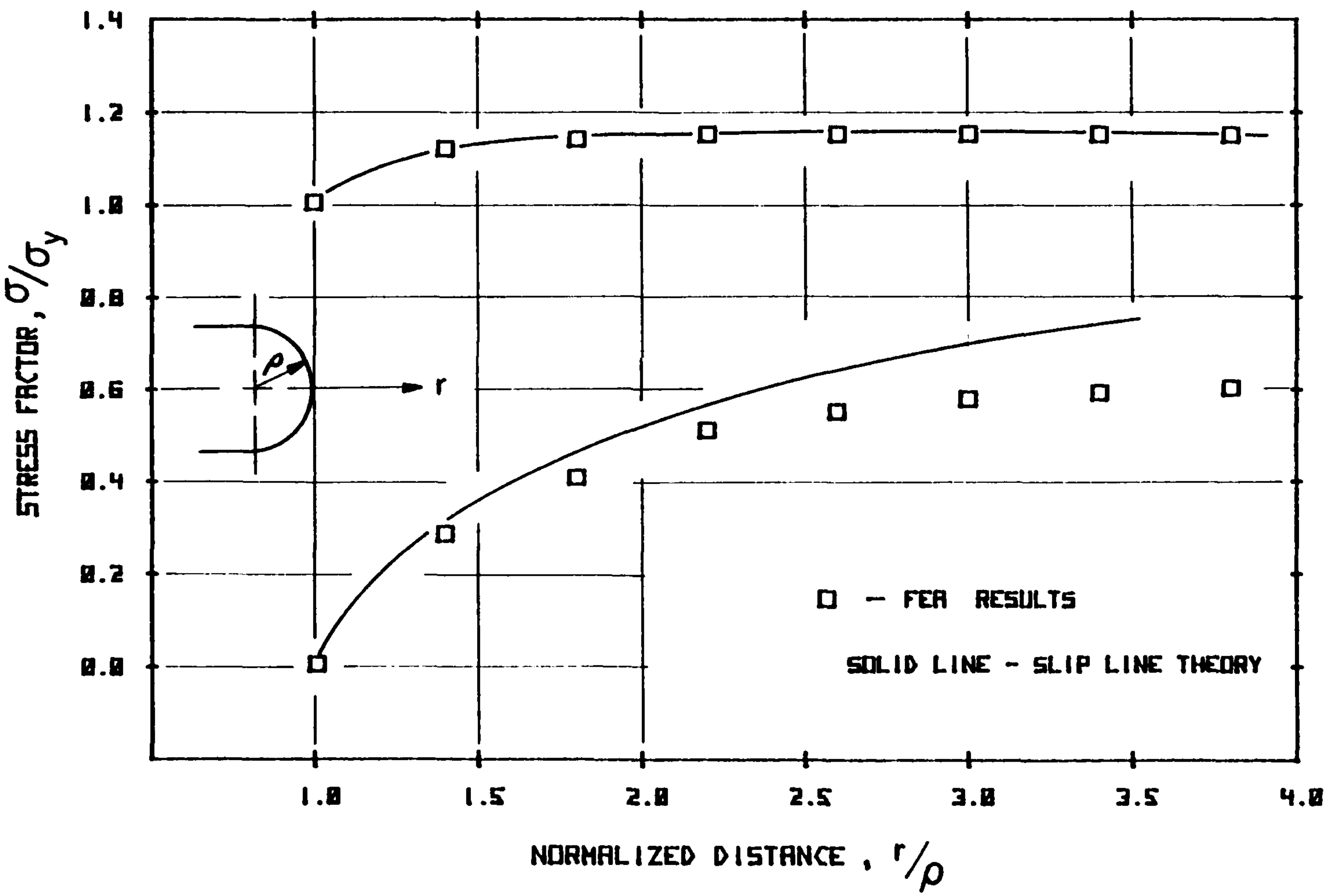


FIGURE 36

DEEP NOTCH 40,000 LB LOAD PLASTIC ZONE

FIGURE 37

RIGID-PERFECTLY-PLASTIC RESULTS



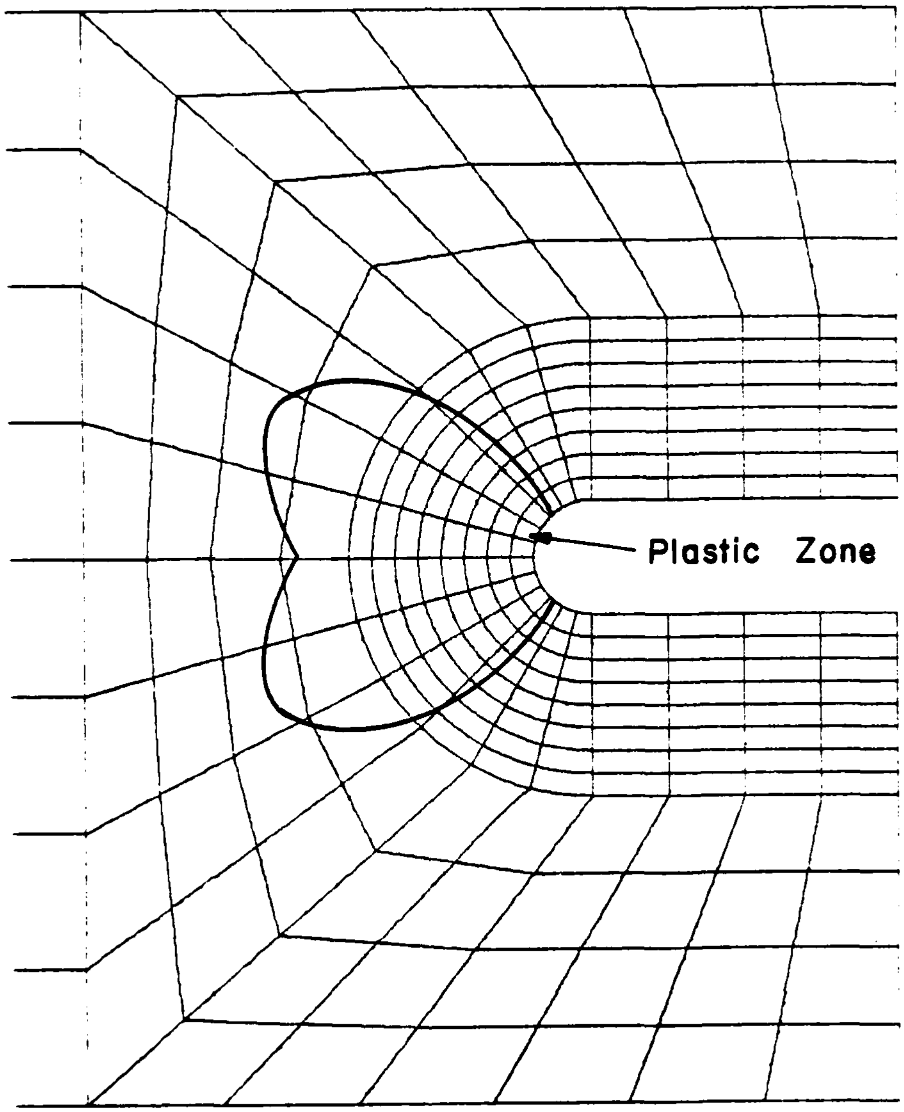


FIGURE 38

RIGID-PERFECTLY-PLASTIC INITIAL PLASTIC ZONE

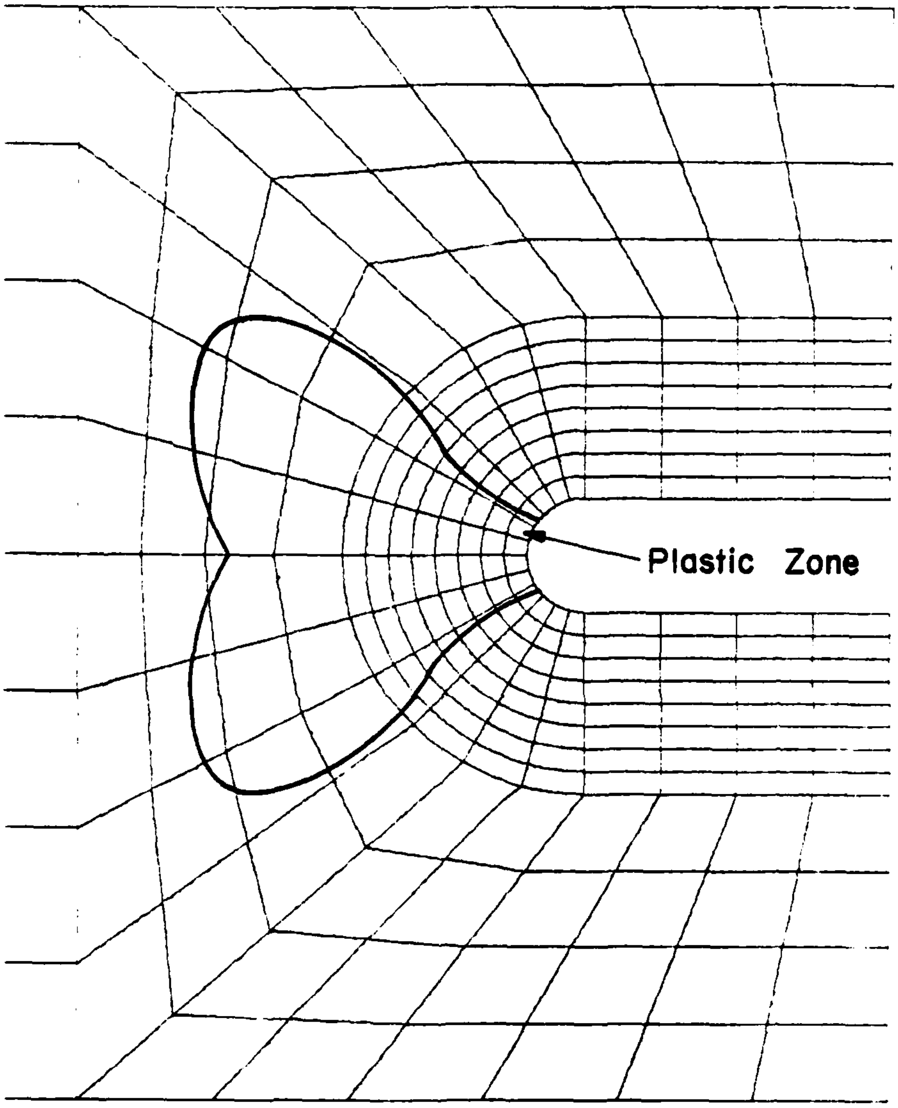


FIGURE 39

RIGID-PERFECTLY-PLASTIC INTERMEDIATE PLASTIC ZONE

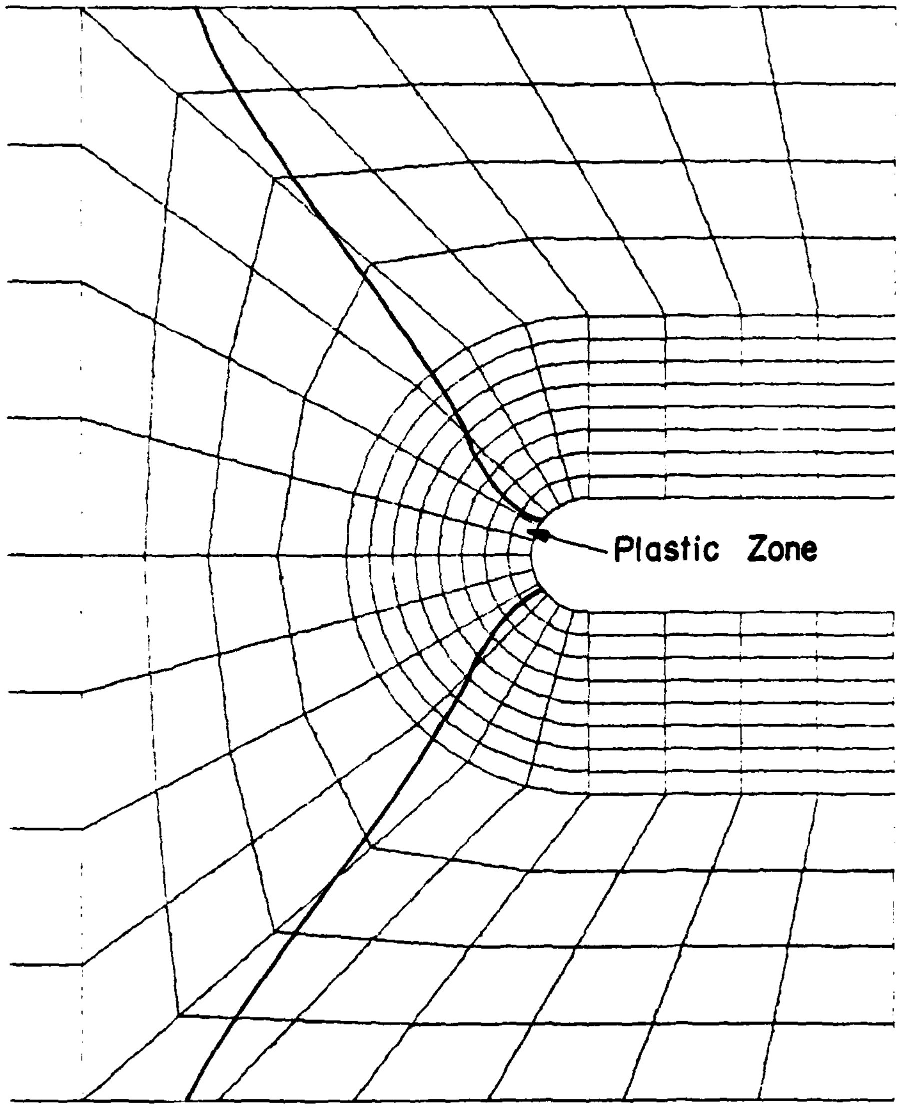


FIGURE 40

RIGIDE-PERFECTLY-PLASTIC FINAL PLASTIC ZONE

TABLE I. MTS AND REIHLE 5 GAGE TEST RESULTS

All Strains are 10^{-6} in/in

MTS Test Machine

LOAD lbs	STRAINS ε_1	ε_2	ε_3	ε_4	ε_5
1000	-3	421	814	1235	1638
2000	338	1003	1619	2279	2903
3000	960	1714	2431	3186	3908

REIHLE Test Machine

LOAD lbs	STRAINS ε_1	ε_2	ε_3	ε_4	ε_5
1000	800	763	755	741	726
2000	1564	1540	1546	1543	1535
3000	2370	2334	2363	2377	2388

TABLE II. MTS SPECIMEN A TEST RESULTS

Cross-section = 0.03975 in^2

Load, lbs.	Strain, ε, 10^{-6} in/in
256	615
503	1204
750	1801
1005	2423
1255	3042
1505	3665
1778	4352
2003	4925
2252	5587
2508	6355
2755	7365
2905	8230
2984	9045
3037	10150

TABLE III. MTS SPECIMEN B TEST RESULTS

Cross-section = 0.03975 in^2

Load, lbs.	Strain, ε, 10^{-6} in/in
500	1250
750	1660
1000	2450
1250	3060
1500	3700
1750	4320
2000	4950
2250	5630
2500	6380
2750	7340
2900	8200
3000	9250
3050	10200
3100	11550
3125	12800

TABLE IV. MTS SPECIMEN C TEST RESULTS

Cross-section = 0.03975 in^2

Load, lbs.	Strain, ε, 10^{-6} in/in
272	660
503	1220
762	1850
1008	2451
1231	3005
1506	3690
1755	4315
2000	4940
2255	5607
2503	6325
2750	7230
2900	8120
3000	9200
3060	10500
3100	11500
3125	12500

TABLE V. REIHLE SPECIMEN TEST RESULTS

Cross-section = 0.12 in^2

LOAD lbs.	STRAIN, ε_1 10^{-6} in/in	STRAIN, ε_2 10^{-6} in/in
500	345	[illegible]
1000	730	[illegible]
1500	1114	[illegible]
2000	1501	-432
2500	1895	[illegible]
3000	2291	-745
3500	2795	-871
4000	3095	-998
4500	3515	[illegible]
5000	3912	-1255
5500	4332	-1414
6000	4750	-1510
6500	5198	-1647
7000	5595	-1784
7500	6075	-1923
8000	6649	-2109
8500	7385	-2275
9000	8668	-2638
9500	12245	-4435

TABLE VI. $\lambda = 0.2$ HOWLANL DATA

DISTANCE FROM HOLE in.	$\sigma_\theta / \sigma_\infty$
0.0	3.14
0.5	1.57
1.0	1.26
1.5	1.16
2.0	1.11
2.5	1.07
3.0	1.05
3.5	1.01
4.0	0.97

TABLE VII. $\lambda = 0.25$ HOWLAND DATA

DISTANCE FROM HOLE in.	$\sigma_\theta / \sigma_\infty$
0.000	3.23
0.422	1.75
0.828	1.30
1.234	1.22
1.641	1.13
2.047	1.07
2.453	1.04
2.859	0.97
3.063	0.95

TABLE VIII. λ = 0.2 FEA RESULTS - NODAL OUTPUT

σ_∞ = 5000 psi

DISTANCE FROM HOLE, in.	σ_θ, psi	σ_r , psi
0.00	15938.2	351.7
0.25	10259.7	2375.8
0.50	7875.7	1783.5
0.75	6877.0	1673.1
1.00	6307.4	1334.7
1.25	5995.4	1087.2
1.50	5797.7	874.4
1.75	5633.9	700.5
2.00	5509.8	556.8

TABLE IX. λ = 0.2 FEA RESULTS - GAUSS OUTPUT

σ_∞ = 5000 psi

DISTANCE FROM HOLE, in.	σ_θ ,psi	σ_r ,psi
0.00	15595.4	128.9
0.25	9482.6	2104.1
0.50	7953.8	1826.6
0.75	6783.7	1650.4
1.00	6316.1	1348.7
1.25	5975.6	1088.9
1.50	5795.8	890.1
1.75	5623.8	695.7
2.00	5499.9	554.9

TABLE X. $\lambda = 0.25$ FEA RESULTS - NODAL OUTPUT

$\sigma_\infty = 4500$ psi

DISTANCE FROM HOLE, in.	σ_θ ,psi	σ_r ,psi
0.00	14745.5	329.8
0.25	9447.0	2181.1
0.50	7232.6	1599.3
0.75	6304.7	1473.5
1.00	5771.7	1139.6
1.25	5471.2	891.6
1.50	5266.9	671.0
1.75	5091.7	489.1
2.00	4940.2	354.5

TABLE XI. $\lambda = 0.25$ FEA RESULTS - GAUSS OUTPUT

$\sigma_\infty = 4500$ psi

DISTANCE FROM HOLE, in.	σ_θ ,psi	σ_r ,psi
0.00	14422.8	121.2
0.25	8721.2	1927.1
0.50	7317.1	1639.7
0.75	6218.6	1452.4
1.00	5779.6	1151.5
1.25	5453.3	891.0
1.50	5267.1	677.3
1.75	5085.9	486.9
2.00	4937.9	343.8

TABLE XII. SHALLOW NOTCH FEA LINEAR RESULTS - NODAL

σ_n = 4225 psi

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.00	11584.9	94.5
0.25	8966.1	1279.9
0.50	7335.6	1501.3
0.75	6347.3	1731.7
1.00	5655.0	1713.2
1.25	5184.1	1703.5
1.50	4832.4	1626.7
1.75	4564.7	1560.6
2.00	4361.1	1484.7

TABLE XIII. SHALLOW NOTCH FEA LINEAR RESULTS - GAUSS

σ_n = 4225 psi

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.00	11530.2	11.5
0.25	8727.1	1177.7
0.50	7355.5	1504.8
0.75	6280.9	1713.6
1.00	5661.2	1720.4
1.25	5159.3	1699.7
1.50	4834.6	1634.2
1.75	4552.8	1561.7
2.00	4353.6	1486.0

TABLE XIV. DEEP NOTCH FEA LINEAR RESULTS - NODAL

σ_n = 4800 psi

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.00	21142.8	755.2
0.25	11929.9	4484.3
0.50	8436.8	3520.4
0.75	6976.6	3324.4
1.00	6076.1	3152.2
1.25	5527.0	2883.4
1.50	5139.2	2623.4
1.75	4842.4	2412.0
2.00	4617.8	2234.2

TABLE XV. DEEP NOTCH FEA LINEAR RESULTS - GAUSS

σ_n = 4800 psi

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.00	20368.1	314.0
0.25	10582.5	4035.2
0.50	8606.0	3611.8
0.75	6852.2	3501.9
1.00	6086.7	3172.2
1.25	5496.1	2884.7
1.50	5141.8	2643.0
1.75	4830.1	2421.2
2.00	4622.0	2238.8

TABLE XVI. SHALLOW NOTCH FEA NONLINEAR 60,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ, psi	σ_r, psi	NO LOAD RESIDUALS σ_θ, psi	NO LOAD RESIDUALS σ_r, psi
0.00	80024.7	1094.5	-33411.4	439.1
0.25	81338.7	9523.3	-4250.0	-2690.1
0.50	81383.6	16052.6	9006.1	2188.8
0.75	65548.3	18993.2	2946.6	2133.4
1.00	58431.4	18799.6	1992.8	1796.7
1.25	52670.1	18347.9	1167.0	1501.6
1.50	49111.1	17477.1	825.7	1250.8
1.75	46080.7	16567.3	594.4	1046.7
2.00	43973.8	15667.8	471.6	885.0

TABLE XVII. SHALLOW NOTCH FEA NONLINEAR 65,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ, psi	σ_r, psi	NO LOAD RESIDUALS σ_θ, psi	NO LOAD RESIDUALS σ_r, psi
0.00	80890.4	1004.6	-42092.1	224.7
0.25	82939.3	10229.5	-9796.3	-2782.0
0.50	83642.7	16054.6	6944.3	-711.2
0.75	74622.0	21475.5	7507.7	3214.2
1.00	64770.4	21171.3	3820.4	2838.7
1.25	57891.2	20593.6	2202.8	2419.0
1.50	53766.7	19537.0	1524.5	2018.5
1.75	50321.1	18474.8	1089.5	1710.1
2.00	47948.2	17421.4	853.7	1448.0

TABLE XVIII. SHALLOW NOTCH FEA NONLINEAR 70,000lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi	NO LOAD RESIDUALS σ_θ ,psi	NO LOAD RESIDUALS σ_r ,psi
0.00	81957.9	704.5	-50670.6	63.9
0.25	82822.6	10668.8	-16176.6	-3285.1
0.50	84007.3	15514.4	-376.9	-2366.8
0.75	87017.4	22662.9	15132.6	2762.3
1.00	71318.0	23765.2	5681.1	3983.0
1.25	63762.9	23215.2	3763.1	3616.6
1.50	58941.5	21920.1	2669.9	3030.0
1.75	54897.6	20670.6	1865.4	2596.7
2.00	52177.0	19426.6	1448.2	2207.0

TABLE XIX. DEEP NOTCH FEA NONLINEAR 30,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi	NO LOAD RESIDUALS σ_θ ,psi	NO LOAD RESIDUALS σ_r ,psi
0.00	83521.0	2332.4	-14138.0	-725.2
0.25	58038.6	20971.3	5680.1	1402.5
0.50	43309.1	18640.5	385.7	824.6
0.75	34402.6	17839.1	198.3	468.9
1.00	30522.9	16076.1	125.0	300.5
1.25	27543.7	14574.8	88.9	215.3
1.50	25757.0	13328.7	67.3	160.7
1.75	24188.8	12195.0	53.5	126.3
2.00	23141.6	11265.7	44.9	100.9

TABLE XX. DEEP NOTCH FEA NONLINEAR 35,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ, psi	σ_r, psi	NO LOAD RESIDUALS σ_θ, psi	NO LOAD RESIDUALS σ_r, psi
0.00	79020.4	1258.1	-39063.2	-1909.2
0.25	78215.7	24598.9	16348.7	1113.1
0.50	50094.6	22675.1	105.7	1699.5
0.75	40516.0	21359.5	624.1	1002.8
1.00	35843.1	19156.9	380.6	716.7
1.25	32290.3	17299.1	257.8	521.7
1.50	30172.9	15782.1	203.5	405.9
1.75	28314.8	14410.8	156.9	319.5
2.00	27079.2	13294.4	133.7	261.5

TABLE XXI. DEEP NOTCH FEA NONLINEAR 40,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ, psi	σ_r, psi	NO LOAD RESIDUALS σ_θ, psi	NO LOAD RESIDUALS σ_r, psi
0.00	80929.5	835.4	-52900.9	-2121.6
0.25	89730.7	24933.8	20503.1	-2132.3
0.50	56572.6	26815.4	-610.4	2977.0
0.75	46984.6	24878.1	1468.2	1643.1
1.00	41400.6	22286.3	610.0	1216.6
1.25	37164.5	20068.3	555.9	892.7
1.50	34690.9	18287.2	438.5	710.5
1.75	32512.6	16672.2	330.7	564.8
2.00	31078.3	15368.8	282.0	470.8

TABLE XXII. RIGID - PERFECTLY - PLASTIC RESULTS

σ_y = 73,000 psi

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.00	73334.4	519.9
0.25	81780.5	20863.6
0.50	83252.6	29813.6
0.75	84074.1	37321.1
1.00	84103.1	40244.0
1.25	84091.8	42244.0
1.50	84051.5	43249.8
1.75	84005.0	44032.9
2.00	83958.1	43875.6

TABLE XXIII. EXPERIMENTAL DATA λ = 0.25 HOLE LINEAR LOADING

σ_∞ = 10,749 psi

DISTANCE FROM HOLE, in.	σ_θ ,psi	σ_r ,psi
0.000	35221.0	49.5
0.125	24639.0	-1650.5
0.250	19809.5	669.5
0.375	17799.0	2311.5
0.500	16588.0	3422.0

TABLE XXIV. EXPERIMENTAL DATA SHALLOW NOTCH LINEAR LOADING

15,000 lb Load

DISTANCE FROM HOLE, in.	σ_θ ,psi	σ_r ,psi
0.000	26611.7	53.2
0.125	22295.0	1392.6
0.250	19999.3	2352.7
0.375	17277.5	2387.6
0.500	15798.7	2880.5
0.625	13679.1	1929.3

TABLE XXV. EXPERIMENTAL DATA SHALLOW NOTCH 60,000 lb LOAD

DISTANCE FROM NOTCH,in.	σ_θ ,psi	σ_r ,psi	NO LOAD RESIDUALS σ_θ ,psi	NO LOAD RESIDUALS σ_r ,psi
0.000	81111.5	5551.0	-23842.0	4.0
0.125	79710.7	6735.8	-19837.0	-475.0
0.250	78112.0	8141.5	-16409.0	-1044.0
0.375	77189.3	11899.5	-12620.0	-1426.0
0.500	71207.2	10509.4	-12319.0	-5008.0
0.625	71436.4	19260.0	-10908.0	-6453.0
0.750	63045.8	16580.9		
0.875	59477.4	17748.6		
1.000	57146.4	19275.4		

TABLE XXVI. EXPERIMENTAL DATA SHALLOW NOTCH 65,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ, psi	σ_r, psi	NO LOAD RESIDUALS σ_θ, psi	NO LOAD RESIDUALS σ_r, psi
0.000	83073.9	7058.0	-36745.0	-191.0
0.125	80957.6	6078.9	-32541.0	-387.0
0.250	79854.9	7468.1	-30256.0	-1554.0
0.375	79482.8	10878.9	-22914.0	-2381.0
0.500	79638.4	16634.0	-20192.0	-2686.0
0.625	77887.0	19867.6	-16300.0	-3392.0
0.750	72556.4	19706.7		
0.875	64863.2	17433.1		
1.000	61648.0	19034.1		

TABLE XXVII. EXPERIMENTAL DATA SHALLOW NOTCH 70,000 lb LOAD

DISTANCE FROM NOTCH, in.	σ_θ, psi	σ_r, psi	NO LOAD RESIDUALS σ_θ, psi	NO LOAD RESIDUALS σ_r, psi
0.000	84748.9	8569.0	-50791.0	43.0
0.125	83492.9	9073.9	-46086.0	-736.0
0.250	84258.3	13718.2	-40774.0	-878.0
0.375	82846.8	13815.0	-34600.0	-1016.0
0.500	82524.6	16814.9	-30017.0	-1316.0
0.625	80446.4	17441.6	-24798.0	-1551.0
0.750	80455.5	23190.4		
0.875	76568.9	22928.7		
1.000	72264.1	23604.0		

TABLE XXVIII. EXPERIMENTAL DATA DEEP NOTCH LINEAR LOADING

15,000 lb Load

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.000	45907.0	-45.0
0.125	35372.0	7693.0
0.250	30410.0	11671.0
0.375	26177.0	12395.0
0.500	20939.0	9879.0
0.625	18373.0	9060.0
0.750	16891.0	8984.0

TABLE XXIX. EXPERIMENTAL DATA DEEP NOTCH 30,000 lb LOAD

Elastic - Plastic

DISTANCE FROM NOTCH, in.	σ_θ ,psi	σ_r ,psi
0.000	76156.6	2587.4
0.125	63996.2	6057.7
0.250	50047.3	10456.3
0.375	43992.3	14485.8
0.500	39748.6	16433.6
0.625	35030.8	15899.3
0.750	33286.8	16728.0

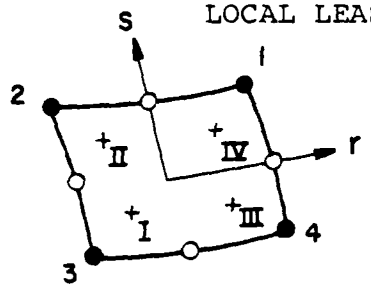
APPENDIX A

PSAP1 JCL

```
     ----- STANDARD JOB CARD -------
// EXEC FRTXCLGP
//FORT.SYSPRINT  DD  DUMMY
//FORT.SYSIN DD UNIT=3330,VOL=SER=DISK02,
// DSN=S2939.PSAP(PSAP),DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(PLOT),
// DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(INIT),
// DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(ELER),
// DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(SAPF),
// DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(ADNA),
// DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(AUXL),
// DISP=SHR,LABEL=(,,,IN)
// DD UNIT=3330,VOL=SER=DISK02,DSN=S2939.PSAP(ADPT),
// DISP=SHR,LABEL=(,,,IN)
// DD *
C *** MAIN PROGRAM ***
      DIMENSION ZZZ(3203),DISPD(5,3,800)
      CALL PSAP1(ZZZ,3203,DISPD,800)
      STOP
      END
************* DELIMITER CARD  (/*) ***************
//GO.FT10F001 DD UNIT=SYSDA,DISP=(,PASS),
// SPACE=(CYL,(2,2)),DSN=&&TEMP1
//GO.SYSIN DD *
*****************************************************
*********  INSERT PSAP1 DATA HERE ***********
*****************************************************
************* DELIMITER CARD  (/*) ***************
```

APPENDIX B

LOCAL LEAST SQUARES SMOOTHING



● Corner Nodes
o Midside Nodes
+ 2x2 Gauss Points

Two-Dimensional Isoparametric Element from ADINA [Ref. 4]

The local smoothing expression from Hinton and Campbell [Ref. 19] in ADINA coordinates becomes

$$\begin{Bmatrix} \tilde{\sigma}_1 \\ \tilde{\sigma}_2 \\ \tilde{\sigma}_3 \\ \tilde{\sigma}_4 \end{Bmatrix} = \begin{bmatrix} C & B & B & A \\ B & A & C & B \\ A & B & B & C \\ B & C & A & B \end{bmatrix} \times \begin{Bmatrix} \sigma_{I} \\ \sigma_{II} \\ \sigma_{III} \\ \sigma_{IV} \end{Bmatrix}$$

where $A = 1 + \frac{\sqrt{3}}{2}$, $B = -\frac{1}{2}$ and $C = 1 - \frac{\sqrt{3}}{2}$.

With $\tilde{\sigma}_1$, $\tilde{\sigma}_2$, $\tilde{\sigma}_3$ and $\tilde{\sigma}_4$ representing the smoothed corner node stresses and σ_{I}, σ_{II}, σ_{III}, and σ_{IV} as the unsmoothed stresses at the Gauss integration points, this expression can be written in an equivalent form.

$$\begin{Bmatrix} \tilde{\sigma}_3 \\ \tilde{\sigma}_4 \\ \tilde{\sigma}_1 \\ \tilde{\sigma}_2 \end{Bmatrix} = \begin{bmatrix} A & B & C & B \\ B & A & B & C \\ C & B & A & B \\ B & C & B & A \end{bmatrix} \times \begin{Bmatrix} \sigma_{I} \\ \sigma_{III} \\ \sigma_{IV} \\ \sigma_{II} \end{Bmatrix}$$

AD-A102 665 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 11/6
AN ELASTIC-PLASTIC FINITE ELEMENT ANALYSIS OF NOTCHED ALUMINUM --ETC(U)
MAR 81 M J KAISER

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The midside node stress values may be obtained by averaging the values at the associated corner nodes, since the distribution of the smoothed stresses is linear along the sides of the element. Smoothed stress values obtained by this least squares method should subsequently be averaged to obtain unique values at nodal points shared by adjacent elements.

APPENDIX C

ADINA JCL

```
     ----- STANDARD JOB CARD -------
// EXEC FORTXCLG,REGION=2000K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD *
      IMPLICIT REAL*8(A-H,O-Z)
      REAL A
      COMMON A(120010)
      MAX=120000
      CALL EXEC(MAX)
      STOP
      END
************* DELIMITER CARD  (/*) ***************
//LKED.USDD DD DISP=SHR,DSN=MSS.S2939.ADINA
//LKED.SYSIN DD *
   INCLUDE USDD(LOADM)
   ENTRY MAIN
************* DELIMITER CARD  (/*) ***************
//GO.FT07F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=4000),SPACE=(CYL,(5,1))
//GO.FT01F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=4000),SPACE=(CYL,(5,1))
//GO.FT02F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=4000),SPACE=(CYL,(5,1))
//GO.FT03F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=1000),SPACE=(CYL,(5,1))
//GO.FT04F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=1000),SPACE=(CYL,(5,1))
//GO.FT08F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=4000),SPACE=(CYL,(5,1))
//GO.FT09F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=4000),SPACE=(CYL,(5,1))
//GO.FT10F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=4000),SPACE=(CYL,(5,1))
//GO.FT11F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=1000),SPACE=(CYL,(5,1))
//GO.FT12F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=1000),SPACE=(CYL,(5,1))
//GO.FT13F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=1000),SPACE=(CYL,(5,1))
//GO.FT56F001 DD UNIT=3330,VOL=SER=DISK01,
// DSN=F0099.TEMP,DISP=SHR,LABEL=(,,,IN)
//GO.FT57F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
//   DCB=(RECFM=VBS,BLKSIZE=1000),SPACE=(CYL,(5,1))
//GO.SYSIN DD *
********************************************
********** INSERT ADINA DATA HERE ***********
********************************************
    --- BLANK CARD ----
    --- BLANK CARD ---     (TWO BLANK CARDS STOP EXEC)
************* DELIMITER CARD  (/*) ***************
```

APPENDIX D

PSAP1 LISTING

```
C        PSAP1        MAR 1981  AS MODIFIED BY LCDR M.J. KAISER        APR1981
C
C     SUBROUTINE PSAP1 DOCUMENTATION
C
C
C
C                     DESCRIPTION OF INPUT DATA CARDS
C
C
C
C     TITLE CARD - 80 ALPHANUMERIC CHARACTERS OF GRAPH TITLE INFORMATION
C                  TO BE PRINTED ABOVE AND BELOW THE GRAPH. THE FIRST 40
C                  CHARACTERS WILL FORM THE FIRST TITLE LINE. THE LAST 40
C                  THE SECOND LINE.
C
C
C     NAMELIST OPTION - CONTAINS VALUES TO VERIFY STORAGE IN BLANK
C                       COMMON AND CONTROL VALUES NEEDED BY THE PROGRAM.
C
C         THE FOLLOWING VALUES ARE INCLUDED---
C
C         NNDEST = ESTIMATE NUMBER OF GRID POINTS TO BE USED.  VALUE MUST
C                  BE GREATER THAN OR EQUAL TO THE ACTUAL NUMBER OF GRID
C                 POINTS.
C             ** DEFAULT = 200 **
C         NUDISP = 0 FOR NO DISPLACEMENT DATA IN X-DIRECTION.
C                = 1 FOR DATA INCLUDING DISPLACEMENTS IN X-DIRECTION.
C             ** DEFAULT = 0 **
C         NVDISP = 0 FOR NO DISPLACEMENT DATA IN Y-DIRECTION.
C                = 1 FOR DATA INCLUDING DISPLACEMENTS IN Y-DIRECTION.
C             ** DEFAULT = 0 **
C         NWDISP = 0 FOR NO DISPLACEMENT DATA IN Z-DIRECTION.
C                = 1 FOR DATA INCLUDING DISPLACEMENTS IN Z-DIRECTION.
C             ** DEFAULT = 0 **
C
C         KGEOM SPECIFIES SUBROUTINE AND CORRESPONDING METHOD OF INPUT
C         FOR MODEL GEOMETRY.
C         KGEOM = 1 FOR USER SUPPLIED SUBROUTINE - GEOM1
C                   GEOM1 DEVELOPED TO READ ADINA GEOMETRY DATA - MAR 77
C               = 2 FOR USER SUPPLIED SUBROUTINE - GEOM2
C               = 9 FOR SAP IV DATA DECK INPUT SUBROUTINE - GEOM9.
C                   GEOM9 READS SAP IV GEOMETRY DATA - MODIFIED  MAR 77
C             ** DEFAULT = 9 **
C         KDATA SPECIFIES SUBROUTINE AND CORRESPONDING METHOD OF INPUT
C         FOR DISPLACEMENT DATA.
C         KDATA = 1 FOR SUBROUTINE DATA1 TO READ IN DISPLACEMENT DATA
C                  -- SUPPLIED BY THE USER.
```

```
C                = 5 FOR SUBROUTINE DATA5 TO READ IN DISPLACEMENT DATA
C                    -- SUPPLIED BY THE USER.
C                = 9 FOR SUBROUTINE DATA9 TO READ SAP IV DATA.
C               ** DEFAULT = 9 **
C        NVALUS - NOT USED AT NPS ----- ALLOW DEFAULT
C
C               ** DEFAULT = 0 **
C          IRESEQ - NOT USED AT NPS ----- ALLOW TO DEFAULT
C               ** DEFAULT = 1 **
C         KPLOT SPECIFIES THE TYPE OF OUTPUT DEVICE TO BE USED.
C         KPLOT = 1 FOR CALCOMP.
C               = 2 FOR LANGLEY RESEARCH CENTER USE ONLY
C               = 3 FOR LRC USE ONLY.
C               = 4 FOR   LRC USE ONLY
C               ** DEFAULT = 1 **
C        YSPACE = SPACE BETWEEN PLOTS IN Y DIRECTION (INCHES) WHEN
C                  MULTIPLE PLOTS ARE PRODUCED. YSPACE/2.0 IS SPACE
C                  BETWEEN TITLE BLOCK AND PLOT.
C               ** DEFAULT = 2.0 **
C         PSIZE  =  PAPER SIZE IN X DIRECTION, USED IN SCALING OF
C                   PLOTS TO INSURE THIS DIMENSION IS NOT EXCEEDED.
C               ** DEFAULT = 9.0 **
C         IDCASE = 0 FOR NO TITLE CARD PRECEDING
C                    DECKS OF DISPLACEMENT VALUES.
C                = 1 FOR TITLE CARD PRECEDING
C                    DECKS OF DISPLACEMENT VALUES.
C               ** DEFAULT = 0 **
C
C
C
C    MODEL GEOMETRY IS NOW INPUT IN ONE OF THE FOLLOWING FORMS,
C       DEPENDING ON THE VALUE OF KGEOM SPECIFIED IN NAMELIST OPTION.
C
C
C      USE IF KGEOM = 1
C        CALL SUBROUTINE GEOM1 WHICH READS ADINA GEOMETRY DATA
C
C      USE IF KGEOM = 2
C        CALL SUBROUTINE GEOM2 WHICH IS PREPARED BY THE USER TO
C        READ GEOMETRY DATA.
C
C
C
C      USE IF KGEOM = 9
C
C         CALL SUBROUTINE GEOM9 WHICH READS SAP IV GEOMETRY DATA.
C
C
```

```
C
C     CASE IDENTIFICATION CARD.
C
C          THIS CARD IS OMITTED IF IDCASE=0 IS SPECIFIED IN &OPTION
C          IF PRESENT, THIS CARD CONTAINS ANY DESIRED ALPHANUMERIC
C          INFORMATION IN COLS.1-80 WILL NOT APPEAR ON PLOT BUT WILL
C          APPEAR ON PRINTOUT ABOVE DISPLACEMENT DATA
C
C
C     DATA TO BE PLOTTED IS NOW INPUT IN ONE OF THE FOLLOWING FORMS,
C          DEPENDING ON THE VALUE OF KDATA SPECIFIED IN NAMELIST OPTION.
C
C
C       USE IF KDATA = 1
C         CALL SUBROUTINE DATA1 WHICH IS PREPARED BY THE USER
C
C
C
C       USE IF KDATA = 5
C         CALL SUBROUTINE DATA5 WHICH IS PREPARED BY THE USER
C
C
C       USE IF KDATA = 9
C
C          CALL SUBROUTINE DATA9 WHICH READS SAP IV DISPLACEMENT DATA.
C          A DISPLACEMENT DATA DECK CAN BE PREPAIRED FOR ADINA IN A
C          FORMAT COMPATABLE WITH DATA9.
C
C
C
C
C      NAMELIST PICT - CONTAINS VALUES NEEDED TO GENERATE PLOTS.
C
C          THE FOLLOWING VALUES ARE INCLUDED---
C
C          KHORZ = INTEGER DESIGNATING HORIZONTAL AXIS OF VIEWING PLANE,
C                   WHERE 1=X, 2=Y, 3=Z.
C               ** DEFAULT = 1 **
C          KVERT = INTEGER DESIGNATING VERTICAL AXIS OF VIEWING PLANE,
C                   WHERE 1=X, 2=Y, 3=Z.
C               ** DEFAULT = 2 **
C          PHI = ANGULAR ROTATION OF MODEL ABOUT ITS X-AXIS, IN DEGREES
C                 (MUST BE TAKEN THIRD).
C               ** DEFAULT = 0.0 **
C          THETA = ANGULAR ROTATION OF MODEL ABOUT ITS Y-AXIS, IN DEGREES
C                 (MUST BE TAKEN SECOND).
C               ** DEFAULT = 0.0 **
C          PSI = ANGULAR ROTATION OF MODEL ABOUT ITS Z-AXIS, IN DEGREES
```

```
C            (MUST BE TAKEN FIRST).                                    DOCU1450
C          ** DEFAULT = 0.0 **                                         DOCU1460
C     NEWFR = 1 FOR FRAME CHANGE BEFORE PLOT IS MADE.                  DOCU1470
C              (A FRAME CHANGE RESETS THE Y-ORIGIN PAST PREVIOUS PLOTDOCU1480
C                BY YSPACE AND X-ORIGIN AT 0.0)                        DOCU1490
C                NEWFR.NE.1 FOR NO FRAME CHANGE BEFORE PLOTTING        DOCU1500
C          ** DEFAULT = 1 **                                           DOCU1510
C     ISCALE = 1 FOR INTERNAL ORIGIN LOCATION AND SCALING.             DOCU1520
C            = 2 FOR USER SPECIFIED ORIGIN AND SCALING.                DOCU1530
C            = 0 FOR NO SCALE CHANGE.(I.E. USE SAME SCALE AS PREVIOUSDOCU1540
C              PLOT) THIS IS USEFUL IN AN ASSEMBLY GRAPH WHERE IT IS DOCU1550
C              NECESSARY TO EXAMINE A MESH IN SECTIONS WITHOUT LOSINGDOCU1560
C              PERSPECTIVE. ISCALE CANNOT BE ZERO ON THE FIRST PLOT. DOCU1570
C          ** DEFAULT = 1 **                                           DOCU1580
C     PLOTSZ = MAXIMUM DIMENSION DESIRED ON COMPLETED PLOT.            DOCU1590
C              (USED FOR SCALING IF ISCALE = 1)                        DOCU1600
C              PLOTSZ SCALES THE PLOT PRIOR TO ROTATION. IF ROTATION DOCU1610
C              CAUSES THE PLOT TO EXCEED PAPER WIDTH (PSIZE), IT IS  DOCU1620
C              RESCALED AND THE PLOT SIZE IS REDUCED ACCORDINGLY.    DOCU1630
C          ** DEFAULT = 10.0 **                                        DOCU1640
C     XORGN = X-LOCATION OF PLOT ORIGIN (USED IF ISCALE = 2).          DOCU1650
C          ** DEFAULT = 0.0 **                                         DOCU1660
C     YORGN = Y-LOCATION OF PLOT ORIGIN (USED IF ISCALE = 2).          DOCU1670
C          ** DEFAULT = 0.0 **                                         DOCU1680
C     PSCALE = MODEL SIZE REDUCTION FACTOR, PSCALE = ACTUAL MODEL      DOCU1690
C              SIZE/DESIRED PLOT SIZE (USED IF ISCALE = 2).            DOCU1700
C          ** DEFAULT = 1.0 **                                         DOCU1710
C     NOTAT = 0 FOR NO NUMBERING ON PLOTS.                             DOCU1720
C           = 1 FOR NUMBERING OF GRID POINTS.                          DOCU1730
C           = 2 FOR NUMBERING OF ELEMENTS.                             DOCU1740
C          ** DEFAULT = 0 **                                           DOCU1750
C     XLHT = HEIGHT OF INTEGERS SPECIFIED BY NOTAT, IN INCHES.         DOCU1760
C          ** DEFAULT = 0.15 **                                        DOCU1770
C     KDISP = 0 FOR UNDEFORMED PLOT.                                   DOCU1780
C           = 1 FOR DEFORMED PLOT.                                     DOCU1790
C           = 2 FOR EXPLODED PLOT.                                     DOCU1800
C           = 3 FOR DISPLACEMENTS REPRESENTED BY VECTORS.              DOCU1810
C          ** DEFAULT = 0 **                                           DOCU1820
C     IDMAG = 1 FOR DIRECT SCALING OF DATA BY DMAGS.                   DOCU1830
C           = 2 FOR SCALING OF DATA TO A MAX. VALUE OF DMAGS.          DOCU1840
C          ** DEFAULT = 2 **                                           DOCU1850
C     DMAGS = MAGNIFICATION OF DISPLACEMENTS (IF KDISP=1).             DOCU1860
C           = REDUCTION FACTOR OF ELEMENTS (IF KDISP=2).               DOCU1870
C          ** DEFAULT = 1.0 **                                         DOCU1880
C     KSYMXY = 1 FOR SYMMETRY ABOUT X-Y PLANE.                         DOCU1890
C          ** DEFAULT = 0 **                                           DOCU1900
C     KSYMXZ = 1 FOR SYMMETRY ABOUT X-Z PLANE.                         DOCU1910
C          ** DEFAULT = 0 **                                           DOCU1920
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C        KSYMYZ = 1 FOR SYMMETRY ABOUT Y-Z PLANE.                         DOCU1930
C             ** DEFAULT = 0 **                                           DOCU1940
C        XXMAX,YYMAX,ZZMAX,XXMIN,YYMIN,ZZMIN LOCATE CUTTING PLANES        DOCU1950
C             PARALLEL TO PRINCIPAL (X-Y,X-Z,Y-Z) PLANES                  DOCU1960
C             TO LIMIT PLOT.                                              DOCU1970
C             ** DEFAULT XXMAX=YYMAX=ZZMAX=1.0E+20 **                     DOCU1980
C             ** DEFAULT XXMIN=YYMIN=ZZMIN=-1.0E+20 **                    DOCU1990
C        NDMAX = MAXIMUM GRID PT. TO BE INCLUDED IN PLOT.                 DOCU2000
C             ** DEFAULT = 9999999999 **                                  DOCU2010
C        NDMIN = MINIMUM GRID PT. TO BE INCLUDED IN PLOT.                 DOCU2020
C             ** DEFAULT = 0 **                                           DOCU2030
C        NELMAX = MAXIMUM ELEMENT NUMBER TO BE INCLUDED IN PLOT.          DOCU2040
C             ** DEFAULT = 9999999999 **                                  DOCU2050
C        NELMIN = MINIMUM ELEMENT NUMBER TO BE INCLUDED IN PLOT.          DOCU2060
C             ** DEFAULT = 0 **                                           DOCU2070
C        KODE SPECIFIES CONTROL OPTION AFTER PLOT IS COMPLETE.            DOCU2080
C        KODE = 0, LAST PLOT, EXIT FROM PROGRAM.                          DOCU2090
C             = 1, READ ANOTHER NAMELIST PICT.                            DOCU2100
C             = 2, READ A NEW SET OF DISPLACEMENT DATA, INCLUDING A       DOCU2110
C                  CASE IDENTIFICATION CARD IF PRESENT.                   DOCU2120
C             = 3, READ A COMPLETE NEW SET OF INPUT DATA,                 DOCU2130
C                  INCLUDING A TITLE CARD.                                DOCU2140
C             ** DEFAULT = 0 **                                           DOCU2150
C                                                                         DOCU2160
C                                                                         DOCU2170
C                                                                         DOCU2180
C     THE ABOVE COMPRISES A COMPLETE BASIC SET OF INPUT DATA IF           DOCU2190
C     KODE = 0 IN &PICT.  FOR KODE = 1, 2, OR 3, ADDITIONAL SECTIONS OF   DOCU2200
C     THE BASIC DECK MUST BE REPEATED.  THE DECK MUST END WITH            DOCU2210
C     NAMELIST &PICT HAVING KODE = 0.                                     DOCU2220
C                                                                         DOCU2230
C                                                                         DOCU2240
C*************************************************************************DOCU2400
C                                                                         DOCU2410
C                                                                         DOCU2420
C                                                                         DOCU2430
C        SUBROUTINE PSAP1 IS A MODIFICATION TO NAVAL POSTGRADUATE         DOCU2440
C        SCHOOL THESIS BY LT. D. M. LOSH , DECEMBER 1976.  MODIFICATION   DOCU2450
C        INCLUDED SAP IV 8-21 NODE BRICK ELEMENTS,BOUNDARY ELEMENTS AND   DOCU2460
C        ADINA TRUSS,PLANE,BRICK ,BEAM ELEMENTS,AND OTHER MINOR           DOCU2470
C        IMPROVEMENTS.                                                    DOCU2480
C                                                                         DOCU2490
C                                                                         DOCU2500
C      MODIFIED BY  ADRIAN E. KIBLER JR.                                  DOCU2510
C                   LT              USN                                   DOCU2520
C                   NAVAL POSTGRADUATE SCHOOL                             DOCU2530
C                   MONTEREY,CA.                                          DOCU2540
C                   JAN - JUN 1977                                        DOCU2550
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C                                                                       DOCU2560
C                                                                       DOCU2570
C***********************************************************************APR1981
C                                                                       APR1981
C                                                                       APR1981
C             ISOLATED GRAPHICS PLOTTING SUBROUTINES                    APR1981
C                                                                       APR1981
C        THE SUBROUTINES USED IN THE ACTUAL CREATION OF PLOTS BY        APR1981
C        THE VERSATEC MODEL 8222A ARE EXPLAINED IN NPS TECHNICAL NOTE   APR1981
C        NUMBER 0141-34,"USING VERSATEC PLOTTER AT NPS".                APR1981
C                                                                       APR1981
C          PSAP1 SJBROUTINES WITH VERSATEC CALL STATEMENTS:             APR1981
C                                                                       APR1981
C            CALCMP       CALPLT       CALNUM       NOTATE              APR1981
C                                                                       APR1981
C            CALWH        CALINE       PSTOP                            APR1981
C                                                                       APR1981
C                                                                       APR1981
C                                                                       APR1981
C  *** ADAPTED FOR VERSATEC BY LCDR MICHAEL J KAISER, JAN 1981 ***      APR1981
C                                                                       APR1981
C                                                                       APR1981
C                                                                       APR1981
C***********************************************************************APR1981
C  ##############################################################       APR1981
C  #                                                            #       APR1981
C  #                                                            #       APR1981
C  #     EXAMPLE OF MAIN PROGRAM USED TO ALLOCATE CORE STORAGE  #       APR1981
C  #      SPACE REQUIRED AND CALL PSAP1:                        #       APR1981
C  #                                                            #       APR1981
C  #          DIMENSION ZZZ(NZ),DISPD(5,3,NON)                  #       APR1981
C  #          CALL PSAP1(ZZZ,NZ,DISPD,NON)                      #       APR1981
C  #          STOP                                              #       APR1981
C  #          END                                               #       APR1981
C  #                                                            #       APR1981
C  #     WHERE:                                                 #       APR1981
C  #                                                            #       APR1981
C  #          NON---MUST BE GREATER THAN NUMBER OF NODES        #       APR1981
C  #                                                            #       APR1981
C  #          NZ----MUST BE GREATER THAN  4 * NON + 3           #       APR1981
C  #              (7*NON+3 IF DISPLACEMENT DATA IS INPUT)       #       APR1981
C  #                                                            #       APR1981
C  #                                                            #       APR1981
C  ##############################################################       APR1981
```

```
      SUBROUTINE PSAP1(ZZZ,NZ,DISPD,NON)
C
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
C
C *** THIS IS THE MAIN SUBROUTINE WHICH CALLS OTHER SUBROUTINES
C
C
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
      INTEGER NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT
      COMMON/CDATA/NTIME,NTLC
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,
     2PSCALE,KDISP,DMAG,KODE
      COMMON/LIMITS/ XXMAX,YYMAX,ZZMAX,XXMIN,YYMIN,ZZMIN,NDMAX,NDMIN,
     1NELMAX,NELMIN
      COMMON/CORGN/ YPMAX,YSPACE,PSIZE
      COMMON/GLOOP/ ILOOP
      COMMON/ABLK/ A(3,3)
      COMMON/SAVEV/ DMAGS,IDMAG
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP
      COMMON/VALUES/ NVALUS
      COMMON/CASEID/ IDCASE
      DIMENSION ZZZ(NZ),DISPD(5,3,NON),ABCD1(10),ABCD2(10),ABCD3(10),
     1ABCD4(10)
      NAMELIST/PICT/ KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,
     1PLOTSZ,XORGN,YORGN,PSCALE,NOTAT,KDISP,IDMAG,DMAGS,KODE,
     2KSYMXY,KSYMXZ,KSYMYZ,XXMAX,YYMAX,ZZMAX,XXMIN,
     3YYMIN,ZZMIN,NDMAX,NDMIN,NELMAX,NELMIN,XLHT
```

```
C                                                                       PSAP0310
C *** TO ZERO NODE AND ELEMENT SJMMATION COUNTERS                        PSAP0320
C                                                                       PSAP0330
      ILOOP = 0                                                         PSAP0340
      NNODE = 0                                                         PSAP0350
      YPMAX=0.0                                                         PSAP0360
C                                                                       PSAP0370
C *** TO DEFINE THE ORIGIN AND OPEN PLOTING DATA SETS                   PSAP0380
C                                                                       PSAP0390
      CALL CALCMP                                                       APR1981
  500 CONTINUE                                                          PSAP0410
      REWIND 10                                                         PSAP0420
      WRITE(6,8)                                                        PSAP0430
    8 FORMAT(1H1)                                                       PSAP0440
C                                                                       PSAP0450
C *** TO READ TITLE CARD FOR RUN                                        PSAP0460
C                                                                       PSAP0470
      READ(5,9004,END=999) (ABCD1(I),I=1,10),(ABCD2(I),I=1,10)          PSAP0480
 9004 FORMAT(20A4)                                                      PSAP0490
      WRITE(6,9006) (ABCD1(I),I=1,10),(ABCD2(I),I=1,10)                 PSAP0500
 9006 FORMAT (///,20X,20A4////)                                         PSAP0510
      CALL INITAL                                                       PSAP0520
C                                                                       PSAP0530
C *** TO PLOT THE TITLE CARD AT THE BEGINING OF THE PLOT                PSAP0540
C                                                                       PSAP0550
      CALL CALPLT(0.0,0.62,3)                                           APR1981
      CALL CALPLT(0.0,0.0,2)                                            APR1981
      CALL CALPLT(9.0,0.0,2)                                            APR1981
      CALL NOTATE(0.8,0.41,0.21,ABCD1,0.0,40)                           APR1981
      CALL NOTATE(0.8,0.10,0.21,ABCD2,0.0,40)                           APR1981
      CALL CALPLT(0.0,1.62+YSPACE/2.0,-3)                               APR1981
C                                                                       PSAP0630
C *** TO SET POINTERS FOR BLANK COMMON STORAGE ZZZ                      PSAP0640
C *** (WITH INTEGER NAMES OF ARRAYS USED IN CALLED SUBROUTINES)         PSAP0650
C                                                                       PSAP0660
      NUMPT = 1                                                         PSAP0670
      XPT = NUMPT+NNDEST                                                PSAP0680
      YPT = XPT+NNDEST                                                  PSAP0690
      ZPT = YPT+NNDEST                                                  PSAP0700
      UPT = ZPT+NNDEST                                                  PSAP0710
      IF(NUDISP.EQ.0) VPT = UPT+1                                       PSAP0720
      IF(NUDISP.NE.0) VPT = UPT+NNDEST                                  PSAP0730
      IF(NVDISP.EQ.0) WPT = VPT+1                                       PSAP0740
      IF(NVDISP.NE.0) WPT = VPT+NNDEST                                  PSAP0750
      IF(NWDISP.EQ.0) NEND = WPT+1-1                                    PSAP0760
      IF(NWDISP.NE.0) NEND = WPT+NNDEST-1                               PSAP0770
      WRITE(6,15) NEND                                                  PSAP0780
   15 FORMAT(///,20X,'BLANK COMMON STORAGE ZZZ REQUIRES AT LEAST ',I6,  PSAP0790
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```
     1' LOCATIONS FOR THIS CASE'///)                                    PSAP0800
      IF(KGEOM.EQ.1) CALL GEOM1                                         PSAP0810
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP0820
      IF(KGEOM.EQ.2) CALL GEOM2                                         PSAP0830
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP0840
      IF(KGEOM.EQ.9) CALL GEOM9                                         PSAP0850
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP0860
      CALL PNTOUT(1,                                                    PSAP0870
     1ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT)) PSAP0880
  600 CONTINUE                                                          PSAP0890
      IF(IDCASE.EQ.0) GO TO 650                                         PSAP0900
      READ(5,9004,END=999) (ABCD3(I),I=1,10),(ABCD4(I),I=1,10)          PSAP0910
      WRITE(6,9006) (ABCD3(I),I=1,10),(ABCD4(I),I=1,10)                 PSAP0920
  650 CONTINUE                                                          PSAP0930
      CALL ZEROO                                                        PSAP0940
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP0950
      IF(KDATA.EQ.1) CALL DATA1                                         PSAP0960
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP0970
      IF(KDATA.EQ.5) CALL DATA5                                         PSAP0980
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP0990
      IF(KDATA.EQ.9) CALL DATA9                                         PSAP1000
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT),PSAP1010
     2DISPD,VON)                                                        PSAP1020
      IF (NUDISP.EQ.0.AND.NVDISP.EQ.0.AND.NWDISP.EQ.0) GO TO 700        PSAP1030
      CALL PNTOUT(2,                                                    PSAP1040
     1ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT)) PSAP1050
  700 CONTINUE                                                          PSAP1060
      IF(KPLOT.EQ.4.AND.ILOOP.NE.0) GO TO 6000                          PSAP1070
      WRITE (6,1000)                                                    PSAP1080
 1000 FORMAT(///)                                                       PSAP1090
      READ(5,PICT)                                                      PSAP1100
      WRITE(6,PICT)                                                     PSAP1110
 6000 CONTINUE                                                          PSAP1120
      CALL DSCALE                                                       PSAP1130
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP1140
      CALL BOUND                                                        PSAP1150
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP1160
      IF(ISCALE.NE.0) CALL ROTAT                                        PSAP1170
      CALL PLOTX                                                        PSAP1180
     1(ZZZ(NUMPT),ZZZ(XPT),ZZZ(YPT),ZZZ(ZPT),ZZZ(UPT),ZZZ(VPT),ZZZ(WPT))PSAP1190
      ILOOP=ILOOP+1                                                     PSAP1200
      GO TO (700,600),KODE                                              PSAP1210
C                                                                       PSAP1220
C *** TO PLOT TITLE ON TOP OF GRAPH IF KODE = 3                         PSAP1230
C *** TO PLOT TITLE ON TOP AND CLOSE PLOTING DATA SETS IF KODE = 0      PSAP1240
C                                                                       PSAP1250
      CALL CALPLT(0.0,YPMAX+YSPACE/2.0,-3)                              APR1981
      CALL CALPLT(0.0,1.0,3)                                            APR1981
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      CALL CALPLT(0.0,1.62,2)                                          APR1981
      CALL CALPLT(9.0,1.62,2)                                          APR1981
      CALL NOTATE(0.8,1.31,.21,ABCD1,0.0,40)                           APR1981
      CALL NOTATE(0.8,1.0,.21,ABCD2,0.0,40)                            APR1981
      CALL CALPLT(0.0,1.62+YSPACE,-3)                                  APR1981
      ILOOP=0                                                          PSAP1340
      IF(KODE.EQ.3) GO TO 500                                          PSAP1350
      WRITE(6,9008)                                                    PSAP1360
 9008 FORMAT(//,5X,'TERMINATION NORMAL DUE TO KODE = 0')               PSAP1370
      CALL PSTOP                                                       APR1981
      RETURN                                                           PSAP1390
  999 CALL ERROR(2)                                                    PSAP1400
      RETURN                                                           PSAP1410
      END                                                              PSAP1420
      SUBROUTINE PLOTX(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                  PLOT0010
C                                                                      PLOT0020
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *PLOT0030
C                                                                      PLOT0040
C *** FOR GENERATING PLOTS.                                            PLOT0050
C *** CALLED BY PSAP1                                                  PLOT0060
C                                                                      PLOT0070
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *PLOT0080
C                                                                      PLOT0090
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT, PLOT0100
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,       PLOT0110
     2PSCALE,KDISP,DMAG,KODE                                           PLOT0120
      COMMON/LIMITS/ XXMAX,YYMAX,ZZMAX,XXMIN,YYMIN,ZZMIN,NDMAX,NDMIN,  PLOT0130
     1NELMAX,NELMIN                                                    PLOT0140
      COMMON/XYZLIM/ XYZMAX(3),XYZMIN(3)                               PLOT0150
      COMMON/CORGN/ YPMAX,YSPACE,PSIZE                                 PLOT0160
      COMMON/GLOOP/ ILOOP                                              PLOT0170
      COMMON/ABLK/ A(3,3)                                              PLOT0180
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP                  PLOT0190
      COMMON/PDELS/ DELX,DELY                                          PLOT0200
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)     PLOT0210
      DIMENSION NODE(20),X(20),Y(20),Z(20),XDISP(20),YDISP(20),        PLOT0220
     1ZDISP(20),XROT(20),YROT(20),XP(23),YP(23)                        PLOT0230
C                                                                      PLOT0240
C *** TO MAKE ALL GRID POINT NUMBERS NEGATIVE                          PLOT0250
C                                                                      PLOT0260
      DO 50 I=1,NNODE                                                  PLOT0270
      IF(NUMPT(I).GT.0) NUMPT(I)=-NUMPT(I)                             PLOT0280
   50 CONTINUE                                                         PLOT0290
C                                                                      PLOT0300
C *** TO MAKE FRAME CHANGE IF NEWFR = 1                                PLOT0310
C ***     NO FRAME CHANGE ON FIRST PLOT AFTER NAMELIST OPTION          PLOT0320
C                                                                      PLOT0330
      YMOVE=0.0                                                        PLOT0340
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      IF(ILOOP.EQ.0) GO TO 70                                           PLOT0350
      IF(NEWFR.EQ.1) YMOVE=YPMAX+YSPACE                                 PLOT0360
   70 CALL CALPLT(0.0,YMOVE,-3)                                         APR1981
      GO TO (710,710,703,710),KPLOT                                     PLOT0380
  703 CONTINUE                                                          PLOT0390
C                                                                       APR1981
  710 CONTINUE                                                          PLOT0410
      IF(ISCALE.NE.0) DELX=0.0                                          PLOT0420
      IF(ISCALE.NE.0) DELY=0.0                                          PLOT0430
      IF(ISCALE.EQ.1) CALL XYSCAL                                       PLOT0440
      CALL CALPLT(XORGN,YORGN,-3)                                       APR1981
      XSHIFT = 0.0                                                      PLOT0460
      YSHIFT = 0.0                                                      PLOT0470
      ZSHIFT = 0.0                                                      PLOT0480
      YPMAX=-1.0E20                                                     PLOT0490
C                                                                       PLOT0500
C *** LOOPS TO ACCOUNT FOR SYMMETRY                                     PLOT0510
C                                                                       PLOT0520
      ZSIGN = +1.0                                                      PLOT0530
      DO 500 II=1,2                                                     PLOT0540
      IF(II.EQ.2.AND.KSYMXY.NE.1) GO TO 500                             PLOT0550
      IF(II.EQ.2.AND.KSYMXY.EQ.1) ZSIGN = -1.0                          PLOT0560
      YSIGN = +1.0                                                      PLOT0570
      DO 510 JJ=1,2                                                     PLOT0580
      IF(JJ.EQ.2.AND.KSYMXZ.NE.1) GO TO 510                             PLOT0590
      IF(JJ.EQ.2.AND.KSYMXZ.EQ.1) YSIGN = -1.0                          PLOT0600
      XSIGN = +1.0                                                      PLOT0610
      DO 520 KK=1,2                                                     PLOT0620
      IF(KK.EQ.2.AND.KSYMYZ.NE.1) GO TO 520                             PLOT0630
      IF(KK.EQ.2.AND.KSYMYZ.EQ.1) XSIGN = -1.0                          PLOT0640
C                                                                       PLOT0650
C *** TO DETERMINE PROJECTED COORDINATES OF ELEMENTS                    PLOT0660
C                                                                       PLOT0670
      REWIND 10                                                         PLOT0680
  100 CONTINUE                                                          PLOT0690
      READ(10,END=1000) NEND,NUMEL,(NODE(J),J=1,NEND)                   PLOT0700
      IF(NUMEL.LT.NELMIN.OR.NUMEL.GT.NELMAX) GO TO 100                  PLOT0710
      DO 10 I=1,NEND                                                    PLOT0720
      ND = NODE(I)                                                      PLOT0730
      IF(NODE(I).EQ.0)GO TO 10                                          PLOT0740
C                                                                       PLOT0750
C *** TO MAKE GRID POINT NUMBERS CONNECTED BY ELEMENTS POSITIVE         PLOT0760
      NUMPT(ND) = IABS(NUMPT(ND))                                       PLOT0770
      IF(NUMPT(ND).LT.NDMIN.OR.NUMPT(ND).GT.NDMAX) GO TO 100            PLOT0780
   10 CONTINUE                                                          PLOT0790
      I = KHORZ                                                         PLOT0800
      J = KVERT                                                         PLOT0810
      DO 20 N=1,NEND                                                    PLOT0820
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      IF(NODE(N).EQ.0) GO TO 20
      ND = NODE(N)
      IF(XPT(ND).GT.XXMAX) GO TO 100
      IF(XPT(ND).LT.XXMIN) GO TO 100
      IF(YPT(ND).GT.YYMAX) GO TO 100
      IF(YPT(ND).LT.YYMIN) GO TO 100
      IF(ZPT(ND).GT.ZZMAX) GO TO 100
      IF(ZPT(ND).LT.ZZMIN) GO TO 100
      XDISP(N) = 0.0
      YDISP(N) = 0.0
      ZDISP(N) = 0.0
      IF(KDISP.EQ.1.AND.NUDISP.NE.0) XDISP(N) = UPT(ND)
      IF(KDISP.EQ.1.AND.NVDISP.NE.0) YDISP(N) = VPT(ND)
      IF(KDISP.EQ.1.AND.NWDISP.NE.0) ZDISP(N) = WPT(ND)
      X(N) = XSIGN*(XPT(ND)+XDISP(N)*DMAG+XSHIFT)/PSCALE
      Y(N) = YSIGN*(YPT(ND)+YDISP(N)*DMAG+YSHIFT)/PSCALE
      Z(N) = ZSIGN*(ZPT(ND)+ZDISP(N)*DMAG+ZSHIFT)/PSCALE
   20 CONTINUE
      IF(KDISP.EQ.2) CALL XPLOD(NEND,X,Y,Z,NODE)
      XCENT = 0.0
      YCENT = 0.0
      FND=0.0
      DO 25 N=1,NEND
      IF(NODE(N).EQ.0) GO TO 25
      XROT(N) = A(I,1)*X(N)+A(I,2)*Y(N)+A(I,3)*Z(N)
      YROT(N) = A(J,1)*X(N)+A(J,2)*Y(N)+A(J,3)*Z(N)
      IF(N.GT.8) GO TO 24
      FND=FND+1.0
      XCENT = XCENT+XROT(N)
      YCENT = YCENT+YROT(N)
   24 CONTINUE
      XROT(N) = XROT(N)+DELX
      YROT(N) = YROT(N)+DELY
       IF(YROT(N).GT.YPMAX) YPMAX=YROT(N)
   25 CONTINUE
      IF(NOTAT.NE.2) GO TO 29
      XCENT = XCENT/FND-(6.0/7.0)*XLHT
      YCENT = YCENT/FND-XLHT/2.0
      XCENT = XCENT+DELX
      YCENT = YCENT+DELY
      AL = NUMEL
   29 CONTINUE
      IF(NOTAT.EQ.2) CALL CALNUM(XCENT,YCENT,XLHT,AL,0.0,-1)
C
C *** TO PLOT ELEMENTS
C
      IF(NEND.EQ.2) GO TO 280
      IF(NEND.EQ.4) GO TO 300
```

```
      IF(NEND.EQ.8) GO TO 320                                           PLOT1310
      IF(NEND.EQ.12) GO TO 340                                          PLOT1320
      IF(NEND.EQ.20) GO TO 340                                          PLOT1330
      CALL ERROR(4)                                                     PLOT1340
C                                                                       PLOT1350
C ***TO PLOT 2 NODE ELEMENT                                             PLOT1360
C                                                                       PLOT1370
  280 CONTINUE                                                          PLOT1380
      CALL CALPLT(XROT(1),YROT(1),3)                                    APR1981
      CALL CALPLT(XROT(2),YROT(2),2)                                    APR1981
      GO TO 430                                                         PLOT1410
C                                                                       PLOT1420
C *** TO PLOT 3 AND 4 NODE PLANE ELEMENT                                PLOT1430
C                                                                       PLOT1440
  300 CONTINUE                                                          PLOT1450
      CALL CALPLT(XROT(1),YROT(1),3)                                    APR1981
      DO 305 NP=2,NEND                                                  PLOT1470
      CALL CALPLT(XROT(NP),YROT(NP),2)                                  APR1981
  305 CONTINUE                                                          PLOT1490
      CALL CALPLT(XROT(1),YROT(1),2)                                    APR1981
      GO TO 430                                                         PLOT1510
C                                                                       PLOT1520
C *** TO PLOT 8 NODE 3-D BRICK                                          PLOT1530
C                                                                       PLOT1540
  320 CONTINUE                                                          PLOT1550
      LP=1                                                              PLOT1560
      DO 330 NP=2,6,4                                                   PLOT1570
          NP2=NP+2                                                      PLOT1580
          CALL CALPLT(XROT(LP),YROT(LP),3)                              APR1981
          DO 325 MP=NP,NP2                                              PLOT1600
              CALL CALPLT(XROT(MP),YROT(MP),2)                          APR1981
  325         CONTINUE                                                  PLOT1620
          CALL CALPLT(XROT(LP),YROT(LP),2)                              APR1981
          LP=LP+4                                                       PLOT1640
  330     CONTINUE                                                      PLOT1650
      DO 335 NP=1,4                                                     PLOT1660
          NP4=NP+4                                                      PLOT1670
          CALL CALPLT(XROT(NP),YROT(NP),3)                              APR1981
          CALL CALPLT(XROT(NP4),YROT(NP4),2)                            APR1981
  335     CONTINUE                                                      PLOT1700
      GO TO 430                                                         PLOT1710
C                                                                       PLOT1720
C *** TO PLOT VARIABLE 4-8 NODE PLANE AND 8-20 NODE BRICK ELEMENTS      PLOT1730
C                                                                       PLOT1740
  340 CONTINUE                                                          PLOT1750
      LP=1                                                              PLOT1760
      KP=8                                                              PLOT1770
      DO 365 NP=2,6,4                                                   PLOT1780
```

```
      NP2=NP+2                                                          PLOT1790
      CALL CALPLT(XROT(LP),YROT(LP),3)                                  APR1981
      DO 345 MP=NP,NP2                                                  PLOT1810
          KP=KP+1                                                       PLOT1820
          N=2                                                           PLOT1830
          CALL CALWH(XP(1),YP(1))                                       APR1981
          XP(2)=XROT(MP)                                                PLOT1850
          YP(2)=YROT(MP)                                                PLOT1860
          XP(3)=XROT(KP)                                                PLOT1870
          YP(3)=YROT(KP)                                                PLOT1880
          IF(NODE(KP).NE.0) CALL CURVE(XP,YP,N)                         PLOT1890
          CALL CALINE(XP,YP,N)                                          APR1981
  345     CONTINUE                                                      PLOT1910
      KP=KP+1                                                           PLOT1920
     N=2                                                                PLOT1930
     CALL CALWH(XP(1),YP(1))                                            APR1981
     XP(2)=XROT(LP)                                                     PLOT1950
     YP(2)=YROT(LP)                                                     PLOT1960
     XP(3)=XROT(KP)                                                     PLOT1970
     YP(3)=YROT(KP)                                                     PLOT1980
     IF(NODE(KP).NE.0) CALL CURVE(XP,YP,N)                              PLOT1990
     CALL CALINE(XP,YP,N)                                               APR1981
  355 LP=LP+4                                                           PLOT2010
      IF(NEND.EQ.12) GO TO 430                                          PLOT2020
  365 CONTINUE                                                          PLOT2030
      DO 390 NP=1,4                                                     PLOT2040
      NP4=NP+4                                                          PLOT2050
      KP=NP+16                                                          PLOT2060
     N=2                                                                PLOT2070
     XP(1)=XROT(NP)                                                     PLOT2080
     YP(1)=YROT(NP)                                                     PLOT2090
     XP(2)=XROT(NP4)                                                    PLOT2100
     YP(2)=YROT(NP4)                                                    PLOT2110
     XP(3)=XROT(KP)                                                     PLOT2120
     YP(3)=YROT(KP)                                                     PLOT2130
     IF(NODE(KP).NE.0) CALL CURVE(XP,YP,N)                              PLOT2140
     CALL CALINE(XP,YP,N)                                               APR1981
  390 CONTINUE                                                          PLOT2160
  430 CONTINUE                                                          PLOT2170
      GO TO 100                                                         PLOT2180
 1000 CONTINUE                                                          PLOT2190
      IF(KDISP.NE.3) GO TO 650                                          PLOT2200
  600 CONTINUE                                                          PLOT2210
C                                                                       PLOT2220
C *** TO PLOT VECTORS AT GRID POINTS                                    PLOT2230
C                                                                       PLOT2240
      DO 601 ND=1,NNODE                                                 PLOT2250
      IF(NUMPT(ND).LE.0) GO TO 601                                      PLOT2260
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      IF(NUMPT(ND).LT.NDMIN.OR.NUMPT(ND).GT.NDMAX) GO TO 601            PLOT2270
      IF(XPT(ND).GT.XYZMAX(1)) GO TO 601                                PLOT2280
      IF(XPT(ND).LT.XYZMIN(1)) GO TO 601                                PLOT2290
      IF(YPT(ND).GT.XYZMAX(2)) GO TO 601                                PLOT2300
      IF(YPT(ND).LT.XYZMIN(2)) GO TO 601                                PLOT2310
      IF(ZPT(ND).GT.XYZMAX(3)) GO TO 601                                PLOT2320
      IF(ZPT(ND).LT.XYZMIN(3)) GO TO 601                                PLOT2330
      X(1) = XSIGN*(XPT(ND)+XSHIFT)/PSCALE                              PLOT2340
      Y(1) = YSIGN*(YPT(ND)+YSHIFT)/PSCALE                              PLOT2350
      Z(1) = ZSIGN*(ZPT(ND)+ZSHIFT)/PSCALE                              PLOT2360
      XDISP(1) = 0.0                                                    PLOT2370
      YDISP(1) = 0.0                                                    PLOT2380
      ZDISP(1) = 0.0                                                    PLOT2390
      IF(NUDISP.NE.0) XDISP(1) = UPT(ND)                                PLOT2400
      IF(NVDISP.NE.0) YDISP(1) = VPT(ND)                                PLOT2410
      IF(NWDISP.NE.0) ZDISP(1) = WPT(ND)                                PLOT2420
      X(2) = XSIGN*(XPT(ND)+XDISP(1)*DMAG+XSHIFT)/PSCALE                PLOT2430
      Y(2) = YSIGN*(YPT(ND)+YDISP(1)*DMAG+XSHIFT)/PSCALE                PLOT2440
      Z(2) = ZSIGN*(ZPT(ND)+ZDISP(1)*DMAG+ZSHIFT)/PSCALE                PLOT2450
      I = KHORZ                                                         PLOT2460
      J = KVERT                                                         PLOT2470
      DO 605 N=1,2                                                      PLOT2480
      XROT(N) = A(I,1)*X(N)+A(I,2)*Y(N)+A(I,3)*Z(N)                     PLOT2490
      YROT(N) = A(J,1)*X(N)+A(J,2)*Y(N)+A(J,3)*Z(N)                     PLOT2500
      XROT(N) = XROT(N)+DELX                                            PLOT2510
      YROT(N) = YROT(N)+DELY                                            PLOT2520
  605 CONTINUE                                                          PLOT2530
      XARW = 0.06                                                       PLOT2540
      YARW = XARW/3.0                                                   PLOT2550
      CALL GARROW(XROT(1),YROT(1),XROT(2),YROT(2),1,XARW,YARW)          PLOT2560
  601 CONTINUE                                                          PLOT2570
  650 CONTINUE                                                          PLOT2580
  520 CONTINUE                                                          PLOT2590
  510 CONTINUE                                                          PLOT2600
  500 CONTINUE                                                          PLOT2610
C                                                                       PLOT2620
C *** TO PLOT NODE POINT NUMBERS                                        PLOT2630
C                                                                       PLOT2640
      IF(NOTAT.EQ.1) CALL NDLET(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)          PLOT2650
      CALL CALPLT(-XORGN,-YORGN,-3)                                     APR1981
C                                                                       PLOT2670
C *** TO MAKE ALL GRID POINT NUMBERS POSITIVE AGAIN                     PLOT2680
C                                                                       PLOT2690
      DO 1100 I=1,NNODE                                                 PLOT2700
      NUMPT(I)=IABS(NUMPT(I))                                           PLOT2710
 1100 CONTINUE                                                          PLOT2720
      RETURN                                                            PLOT2730
      END                                                               PLOT2740
```

```
      SUBROUTINE CURVE(XP,YP,N)                                         PLOT2750
C                                                                       PLOT2760
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT2770
C                                                                       PLOT2780
C *** THIS SUBROUTINE INTERPOLATES ALONG THE EDGES OF ISOPARAMETRIC     PLOT2790
C *** ELEMENTS USING SHAPE FUNCTIONS                                    PLOT2800
C *** CALLED BY PLOTX                                                   PLOT2810
C                                                                       PLOT2820
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT2830
C                                                                       PLOT2840
      DIMENSION XP(1),YP(1)                                             PLOT2850
      DIMENSION X(3),Y(3)                                               PLOT2860
      DO 100 I=1,3                                                      PLOT2870
         X(I)=XP(I)                                                     PLOT2880
         Y(I)=YP(I)                                                     PLOT2890
  100    CONTINUE                                                       PLOT2900
      R=-1.0                                                            PLOT2910
      DO 200 I=1,21                                                     PLOT2920
      YP(I)=Y(1)*R*(R-1.0)/2.0-Y(3)*(R+1.0)*(R-1.0)+Y(2)*R*(R+1.0)/2.0  PLOT2930
      XP(I)=X(1)*R*(R-1.0)/2.0-X(3)*(R+1.0)*(R-1.0)+X(2)*R*(R+1.0)/2.0  PLOT2940
         R=R+0.1                                                        PLOT2950
  200    CONTINUE                                                       PLOT2960
      N=21                                                              PLOT2970
      RETURN                                                            PLOT2980
      END                                                               PLOT2990
      SUBROUTINE DSCALE(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                  PLOT3000
C                                                                       PLOT3010
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT3020
C                                                                       PLOT3030
C *** THIS SUBROUTINE DETERMINES THE SCALE FACTOR FOR DISPLACEMENTS     PLOT3040
C *** CALLED BY PSAP1                                                   PLOT3050
C                                                                       PLOT3060
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT3070
C                                                                       PLOT3080
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT, PLOT3090
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,        PLOT3100
     2PSCALE,KDISP,DMAG,KODE                                            PLOT3110
      COMMON/SAVEV/ DMAGS,IDMAG                                         PLOT3120
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP                   PLOT3130
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)      PLOT3140
      IF(KDISP.EQ.0.OR.KDISP.EQ.2) GO TO 10                             PLOT3150
      GO TO (10,20), IDMAG                                              PLOT3160
   10 CONTINUE                                                          PLOT3170
      DMAG = DMAGS                                                      PLOT3180
      GO TO 30                                                          PLOT3190
   20 CONTINUE                                                          PLOT3200
      DMAX = 0.0                                                        PLOT3210
      DO 100 I=1,NNODE                                                  PLOT3220
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      IF(NUDISP.EQ.0) GO TO 500                                         PLOT3230
      IF(ABS(UPT(I)).GT.DMAX) DMAX = ABS(UPT(I))                        PLOT3240
  500 CONTINUE                                                          PLOT3250
      IF(NVDISP.EQ.0) GO TO 501                                         PLOT3260
      IF(ABS(VPT(I)).GT.DMAX) DMAX = ABS(VPT(I))                        PLOT3270
  501 CONTINUE                                                          PLOT3280
      IF(NWDISP.EQ.0) GO TO 502                                         PLOT3290
      IF(ABS(WPT(I)).GT.DMAX) DMAX = ABS(WPT(I))                        PLOT3300
  502 CONTINUE                                                          PLOT3310
  100 CONTINUE                                                          PLOT3320
      DMAG = DMAGS/DMAX                                                 PLOT3330
   30 CONTINUE                                                          PLOT3340
      RETURN                                                            PLOT3350
      END                                                               PLOT3360
      SUBROUTINE ROTAT                                                  PLOT3370
C                                                                       PLOT3380
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT3390
C                                                                       PLOT3400
C *** SETS UP COEFFICIENTS OF ROTATION MATRIX                           PLOT3410
C *** CALLED BY PSAP1                                                   PLOT3420
C                                                                       PLOT3430
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT3440
C                                                                       PLOT3450
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT, PLOT3460
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,        PLOT3470
     2PSCALE,KDISP,DMAG,KODE                                            PLOT3480
      COMMON/ABLK/ A(3,3)                                               PLOT3490
      PI = 3.1415926536                                                 PLOT3500
      SINPHI = SIN(PHI*PI/180.0)                                        PLOT3510
      COSPHI = COS(PHI*PI/180.0)                                        PLOT3520
      SINTHE = SIN(THETA*PI/180.0)                                      PLOT3530
      COSTHE = COS(THETA*PI/180.0)                                      PLOT3540
      SINPSI = SIN(PSI*PI/180.0)                                        PLOT3550
      COSPSI = COS(PSI*PI/180.0)                                        PLOT3560
      A(1,1) = COSTHE*COSPSI                                            PLOT3570
      A(1,2) = COSPSI*SINTHE*SINPHI-SINPSI*COSPHI                       PLOT3580
      A(1,3) = SINTHE*COSPHI*COSPSI+SINPHI*SINPSI                       PLOT3590
      A(2,1) = SINPSI*COSTHE                                            PLOT3600
      A(2,2) = SINTHE*SINPHI*SINPSI+COSPHI*COSPSI                       PLOT3610
      A(2,3) = SINTHE*COSPHI*SINPSI-SINPHI*COSPSI                       PLOT3620
      A(3,1) = -SINTHE                                                  PLOT3630
      A(3,2) = COSTHE*SINPHI                                            PLOT3640
      A(3,3) = COSTHE*COSPHI                                            PLOT3650
      RETURN                                                            PLOT3660
      END                                                               PLOT3670
      SUBROUTINE XYSCAL                                                 PLOT3680
C                                                                       PLOT3690
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT3700
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C *** TO DETERMINE SCALE FACTOR FOR MODEL GEOMETRY.                     PLOT3720
C *** CALLED BY PLOTX                                                   PLOT3730
C                                                                       PLOT3740
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *    PLOT3750
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT, PLOT3770
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,        PLOT3780
     2PSCALE,KDISP,DMAG,KODE                                            PLOT3790
      COMMON/XYZLIM/ XYZMAX(3),XYZMIN(3)                                PLOT3800
      COMMON/CORGN/ YPMAX,YSPACE,PSIZE                                  PLOT3810
      COMMON/ABLK/ A(3,3)                                               PLOT3820
      COMMON/PDELS/ DELX,DELY                                           PLOT3830
      I = KHORZ                                                         PLOT3840
      J = KVERT                                                         PLOT3850
      DMAX = 0.0                                                        PLOT3860
      DO 5 N=1,3                                                        PLOT3870
      VDUM = ABS(XYZMAX(N)-XYZMIN(N))                                   PLOT3880
      IF(VDUM.GT.DMAX) DMAX = VDUM                                      PLOT3890
    5 CONTINUE                                                          PLOT3900
      PSCALE = DMAX/PLOTSZ                                              PLOT3910
      DO 10 L=1,2                                                       PLOT3920
      DO 10 M=1,2                                                       PLOT3930
      DO 10 N=1,2                                                       PLOT3940
      X = XYZMIN(1)                                                     PLOT3950
      IF(L.EQ.2) X = XYZMAX(1)                                          PLOT3960
      Y = XYZMIN(2)                                                     PLOT3970
      IF(M.EQ.2) Y = XYZMAX(2)                                          PLOT3980
      Z = XYZMIN(3)                                                     PLOT3990
      IF(N.EQ.2) Z = XYZMAX(3)                                          PLOT4000
      XROT = A(I,1)*X+A(I,2)*Y+A(I,3)*Z                                 PLOT4010
      YROT = A(J,1)*X+A(J,2)*Y+A(J,3)*Z                                 PLOT4020
      IF(L*M*N.NE.1) GO TO 30                                           PLOT4030
   20 CONTINUE                                                          PLOT4040
      XRMIN = XROT                                                      PLOT4050
      XRMAX = XROT                                                      PLOT4060
      YRMIN = YROT                                                      PLOT4070
      YRMAX = YROT                                                      PLOT4080
   30 CONTINUE                                                          PLOT4090
      IF(XROT.GT.XRMAX) XRMAX = XROT                                    PLOT4100
      IF(XROT.LT.XRMIN) XRMIN = XROT                                    PLOT4110
      IF(YROT.GT.YRMAX) YRMAX = YROT                                    PLOT4120
      IF(YROT.LT.YRMIN) YRMIN = YROT                                    PLOT4130
   10 CONTINUE                                                          PLOT4140
      XR=ABS(XRMAX-XRMIN)                                               PLOT4150
      IF(XR/PSCALE.GT.PSIZE) PSCALE=XR/PSIZE                            PLOT4160
      XRMAX = XRMAX/PSCALE                                              PLOT4170
      YRMAX = YRMAX/PSCALE                                              PLOT4180
      XRMIN = XRMIN/PSCALE                                              PLOT4190
      YRMIN = YRMIN/PSCALE                                              PLOT4200
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      DELX = -XRMIN
      DELY = -YRMIN
      XORGN = (PSIZE-XR/PSCALE)/2.0
      YORGN = 0.0
      RETURN
      END
      SUBROUTINE XPLOD(NEND,X,Y,Z,NODE)
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
C *** FOR GENERATING EXPLODED PLOTS.
C *** CALLED BY PLOTX
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,
     2PSCALE,KDISP,DMAG,KODE
      DIMENSION X(20),Y(20),Z(20),NODE(20)
C
C *** TO CALCULATE THE INCENTER OF TRIANGLES
C
      IF(NODE(4).EQ.0) NEND=3
      IF(NEND.NE.3) GO TO 20
   10 CONTINUE
      A = SQRT((X(2)-X(3))**2+(Y(2)-Y(3))**2+(Z(2)-Z(3))**2)
      B = SQRT((X(1)-X(3))**2+(Y(1)-Y(3))**2+(Z(1)-Z(3))**2)
      C = SQRT((X(1)-X(2))**2+(Y(1)-Y(2))**2+(Z(1)-Z(2))**2)
      AC1 = A/(A+B+C)
      AC2 = B/(A+B+C)
      AC3 = C/(A+B+C)
      XOC = AC1*X(1)+AC2*X(2)+AC3*X(3)
      YOC = AC1*Y(1)+AC2*Y(2)+AC3*Y(3)
      ZOC = AC1*Z(1)+AC2*Z(2)+AC3*Z(3)
      GO TO 190
   20 CONTINUE
C
C *** TO CALCULATE THE CENTROID OF RODS,BARS,AND QUADS
C
      XOC = 0.0
      YOC = 0.0
      ZOC = 0.0
      FND=0.0
      DO 100 I=1,NEND
      IF(NODE(I).EQ.0) GO TO 100
      IF(I.GT.8) GO TO 101
      FND=FND+1.0
      XOC = XOC+X(I)
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      YOC = YOC+Y(I)                                                    PLOT4690
      ZOC = ZOC+Z(I)                                                    PLOT4700
  100 CONTINUE                                                          PLOT4710
  101 CONTINJE                                                          PLOT4720
      XOC=XOC/FND                                                       PLOT4730
      YOC=YOC/FND                                                       PLOT4740
      ZOC=ZOC/FND                                                       PLOT4750
  190 CONTINUE                                                          PLOT4760
C                                                                       PLOT4770
C *** TO REDUCE THE SIZE OF THE ELEMENT                                 PLOT4780
C                                                                       PLOT4790
      DO 200 I=1,NEND                                                   PLOT4800
      IF(NODE(I).EQ.0) GO TO 200                                        PLOT4810
      X(I) = X(I)*DMAG                                                  PLOT4820
      Y(I) = Y(I)*DMAG                                                  PLOT4830
      Z(I) = Z(I)*DMAG                                                  PLOT4840
  200 CONTINJE                                                          PLOT4850
C                                                                       PLOT4860
C *** TO CALCULATE THE CENTROID OF THE REDUCED ELEMENT                  PLOT4870
C                                                                       PLOT4880
      XRC = XOC*DMAG                                                    PLOT4890
      YRC = YOC*DMAG                                                    PLOT4900
      ZRC = ZOC*DMAG                                                    PLOT4910
C                                                                       PLOT4920
C *** SHIFT CORNERS OF ORIGINAL AND REDUCED TO MAKE CENTROIDS MATCH     PLOT4930
C                                                                       PLOT4940
      DO 400 I=1,NEND                                                   PLOT4950
      IF(NODE(I).EQ.0) GO TO 400                                        PLOT4960
      X(I) = X(I)+(XOC-XRC)                                             PLOT4970
      Y(I) = Y(I)+(YOC-YRC)                                             PLOT4980
      Z(I) = Z(I)+(ZOC-ZRC)                                             PLOT4990
  400 CONTINJE                                                          PLOT5000
      RETURN                                                            PLOT5010
      END                                                               PLOT5020
      SUBROUTINE GARROW(X1,Y1,X2,Y2,NC,XHEAD,YHEAD)                     PLOT5030
C                                                                       PLOT5040
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT5050
C                                                                       PLOT5060
C *** TO DRAW ARROWS FROM X1,Y1 TO X2,Y2.                               PLOT5070
C *** CALLED BY PLOTX                                                   PLOT5080
C                                                                       PLOT5090
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * PLOT5100
C                                                                       PLOT5110
      DEN = SQRT((X2-X1)**2+(Y2-Y1)**2)                                 PLOT5120
      IF(DEN.EQ.0.0) GO TO 5000                                         PLOT5130
      C = (X1-X2)/DEN                                                   PLOT5140
      S = (Y1-Y2)/DEN                                                   PLOT5150
      CALL CALPLT(X1,Y1,3)                                              APR1981
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      CALL CALPLT(X2,Y2,2)                                              APR1981
      IF(NC.LT.1) GO TO 1000                                            PLOT5180
      XA = X2+(C*XHEAD-S*YHEAD)                                         PLOT5190
      YA = Y2+(S*XHEAD+C*YHEAD)                                         PLOT5200
      CALL CALPLT(XA,YA,2)                                              APR1981
      IF(NC.LT.2) GO TO 1000                                            PLOT5220
      XB = X2+(C*XHEAD-S*(-YHEAD))                                      PLOT5230
      YB = Y2+(S*XHEAD+C*(-YHEAD))                                      PLOT5240
      CALL CALPLT(XB,YB,2)                                              APR1981
      IF(NC.LT.3) GO TO 1000                                            PLOT5260
      CALL CALPLT(X2,Y2,2)                                              APR1981
      IF(NC.LT.4) GO TO 1000                                            PLOT5280
      XC = X2+(-S*YHEAD)                                                PLOT5290
      YC = Y2+(+C*YHEAD)                                                PLOT5300
      CALL CALPLT(XC,YC,2)                                              APR1981
      IF(NC.LT.5) GO TO 1000                                            PLOT5320
      XD = X2+(-S*(-YHEAD))                                             PLOT5330
      YD = Y2+(+C*(-YHEAD))                                             PLOT5340
      CALL CALPLT(XD,YD,2)                                              APR1981
 1000 CONTINUE                                                          PLOT5360
      CALL CALPLT(X2,Y2,3)                                              APR1981
 5000 CONTINUE                                                          PLOT5380
      RETURN                                                            PLOT5390
      END                                                               PLOT5400
      SUBROUTINE NDLET(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                   PLOT5410
C                                                                       PLOT5420
C *      *    *    *    *    *    *    *    *    *    *    *    *    *  PLOT5430
C                                                                       PLOT5440
C *** FOR ANNOTATING GRID POINT NUMBERS ON PLOTS.                       PLOT5450
C *** CALLED BY PSAP1                                                   PLOT5460
C                                                                       PLOT5470
C *      *    *    *    *    *    *    *    *    *    *    *    *    *  PLOT5480
C                                                                       PLOT5490
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT, PLOT5500
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,        PLOT5510
     2PSCALE,KDISP,DMAG,KODE                                            PLOT5520
      COMMON/LIMITS/ XXMAX,YYMAX,ZZMAX,XXMIN,YYMIN,ZZMIN,NDMAX,NDMIN,   PLOT5530
     1NELMAX,NELMIN                                                     PLOT5540
      COMMON/XYZLIM/ XYZMAX(3),XYZMIN(3)                                PLOT5550
      COMMON/ABLK/ A(3,3)                                               PLOT5560
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP                   PLOT5570
      COMMON/PDELS/ DELX,DELY                                           PLOT5580
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)      PLOT5590
      II = KHORZ                                                        PLOT5600
      JJ = KVERT                                                        PLOT5610
      XSHIFT = 0.0                                                      PLOT5620
      YSHIFT = 0.0                                                      PLOT5630
      ZSHIFT = 0.0                                                      PLOT5640
```

```
      DO 500 I=1,NNODE                                                  PLOT5650
      IF(NUMPT(I).LE.0) GO TO 500                                       PLOT5660
      IF(NUMPT(I).LT.NDMIN.OR.NUMPT(I).GT.NDMAX) GO TO 500              PLOT5670
      IF(XPT(I).GT.XYZMAX(1)) GO TO 500                                 PLOT5680
      IF(XPT(I).LT.XYZMIN(1)) GO TO 500                                 PLOT5690
      IF(YPT(I).GT.XYZMAX(2)) GO TO 500                                 PLOT5700
      IF(YPT(I).LT.XYZMIN(2)) GO TO 500                                 PLOT5710
      IF(ZPT(I).GT.XYZMAX(3)) GO TO 500                                 PLOT5720
      IF(ZPT(I).LT.XYZMIN(3)) GO TO 500                                 PLOT5730
      X = (XPT(I)+XSHIFT)/PSCALE                                        PLOT5740
      Y = (YPT(I)+YSHIFT)/PSCALE                                        PLOT5750
      Z = (ZPT(I)+ZSHIFT)/PSCALE                                        PLOT5760
      XROT = A(II,1)*X+A(II,2)*Y+A(II,3)*Z                              PLOT5770
      YROT = A(JJ,1)*X+A(JJ,2)*Y+A(JJ,3)*Z                              PLOT5780
      XL = XROT+XLHT/2.0                                                PLOT5790
      YL = YROT+XLHT/2.0                                                PLOT5800
      XL = XL+DELX                                                      PLOT5810
      YL = YL+DELY                                                      PLOT5820
      AL = NUMPT(I)                                                     PLOT5830
      CALL CALNUM(XL,YL,XLHT,AL,0.0,-1)                                 APR1981
  500 CONTINUE                                                          PLOT5850
      RETURN                                                            PLOT5860
      END                                                               PLOT5870
```

```
      SUBROUTINE INITAL
C
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
C
C *** TO SET UP VALUES FOR CONTROL PARAMETERS
C *** CALLED BY PSAP1
C
C
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
      COMMON/CDATA/NTIME,NTLC
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALF,PLOTSZ,XORGN,YORGN,
     2PSCALE,KDISP,DMAG,KODE
      COMMON/LIMITS/ XXMAX,YYMAX,ZZMAX,XXMIN,YYMIN,ZZMIN,NDMAX,NDMIN,
     1NELMAX,NELMIN
      COMMON/CORGN/ YPMAX,YSPACE,PSIZE
      COMMON/SAVEV/ DMAGS,IDMAG
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP
      COMMON/SEQNCE/ IRESEQ
      COMMON/VALUES/ NVALUS
      COMMON/CASEID/ IDCASE
      NAMELIST/OPTION/ NNDEST,NUDISP,NVDISP,NWDISP,
     1KGEOM,KDATA,NVALUS,IRESEQ,KPLOT,YSPACE,PSIZE,IDCASE
C
C *** DESCRIPTION OF VALUES IN &OPTION GIVEN IN SUBROUTINE DOCMNT
C
C
C *** TO SET DEFAULT VALUES FOR &OPTION
C
      NNDEST = 200
      NUDISP=0
      NVDISP=0
      NWDISP=0
      KGEOM=9
      KDATA=9
      NTIME=0
      NVALUS = 0
      IRESEQ = 1
      KPLOT = 1
      YSPACE=2.0
      PSIZE=9.0
      IDCASE = 0
C
C *** TO SET DEFAULT VALUES FOR &PICT
C
      KHORZ = 1
```

```
      KVERT = 2
      PHI = 0.0
      THETA = 0.0
      PSI = 0.0
      NEWFR = 1
      ISCALE = 1
      PLOTSZ = 10.0
      XORGN = 0.0
      YCRGN = 0.0
      PSCALE = 1.0
      NOTAT = 0
      XLHT = 0.1400
      KDISP = 0
      IDMAG = 2
      DMAGS = 1.0
      KSYMXY = 0
      KSYMXZ = 0
      KSYMYZ = 0
      XXMAX = 1.0E20
      YYMAX = 1.0E20
      ZZMAX = 1.0E20
      XXMIN = -1.0E20
      YYMIN = -1.0E20
      ZZMIN = -1.0E20
      NDMAX = 9999999
      NDMIN = 0
      NELMAX = 9999999
      NELMIN = 0
      KODE = 0
      READ(5,OPTION,END=999)
      WRITE(6,9010)
 9010 FORMAT(////)
      WRITE(6,OPTION)
      WRITE(6,9010)
      RETURN
  999 CALL ERROR(3)
      RETURN
      END
      SUBROUTINE BOUND(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
C *** TO DETERMINE MAXIMUM DIMENSIONAL LIMITS OF BODY FOR USE
C     IN SCALING PLOTS
C *** CALLED BY PSAP1
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
```

```
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,
     2PSCALE,KDISP,DMAG,KODE
      COMMON/LIMITS/ XXMAX,YYMAX,ZZMAX,XXMIN,YYMIN,ZZMIN,NDMAX,NDMIN,
     1NELMAX,NELMIN
      COMMON/XYZLIM/ XYZMAX(3),XYZMIN(3)
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)
      DIMENSION NODE(20)
      DO 5 I=1,3
      XYZMIN(I) = +1.0E20
      XYZMAX(I) = -1.0E20
    5 CONTINUE
      REWIND 10
  100 CONTINUE
      READ(10,END=1000) NEND,NUMEL,(NODE(I),I=1,NEND)
      IF(NUMEL.LT.NELMIN.OR.NUMEL.GT.NELMAX) GO TO 100
      DO 10 I=1,NEND
      ND = NODE(I)
      IF(NODE(I).EQ.0) GO TO 10
      IF(NUMPT(ND).LT.NDMIN.OR.NUMPT(ND).GT.NDMAX) GO TO 100
   10 CONTINUE
      DO 20 I=1,NEND
      IF(NODE(I).EQ.0) GO TO 20
      ND = NODE(I)
      IF(XPT(ND).GT.XXMAX) GO TO 20
      IF(XPT(ND).LT.XXMIN) GO TO 20
      IF(YPT(ND).GT.YYMAX) GO TO 20
      IF(YPT(ND).LT.YYMIN) GO TO 20
      IF(ZPT(ND).GT.ZZMAX) GO TO 20
      IF(ZPT(ND).LT.ZZMIN) GO TO 20
      IF(XPT(ND).GT.XYZMAX(1)) XYZMAX(1) = XPT(ND)
      IF(XPT(ND).LT.XYZMIN(1)) XYZMIN(1) = XPT(ND)
      IF(YPT(ND).GT.XYZMAX(2)) XYZMAX(2) = YPT(ND)
      IF(YPT(ND).LT.XYZMIN(2)) XYZMIN(2) = YPT(ND)
      IF(ZPT(ND).GT.XYZMAX(3)) XYZMAX(3) = ZPT(ND)
      IF(ZPT(ND).LT.XYZMIN(3)) XYZMIN(3) = ZPT(ND)
   20 CONTINUE
      GO TO 100
 1000 CONTINUE
      DO 300 I=1,3
      IF(I.EQ.1.AND.KSYMYZ.NE.1) GO TO 300
      IF(I.EQ.2.AND.KSYMXZ.NE.1) GO TO 300
      IF(I.EQ.3.AND.KSYMXY.NE.1) GO TO 300
      XYZBIG = ABS(XYZMAX(I))
      IF(ABS(XYZMIN(I)).GT.XYZBIG) XYZBIG = ABS(XYZMIN(I))
      XYZMAX(I) = XYZBIG
      XYZMIN(I) = -XYZBIG
```

```
  300 CONTINUE
      RETURN
      END
      SUBROUTINE ZEROD(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
C *** INITIALIZES ALL DISPLACEMENTS TO ZERO.
C *** CALLED BY PSAP1
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)
      IF(NUDISP.EQ.0) GO TO 200
      DO 150 I=1,NUDISP
      UPT(I) = 0.0
  150 CONTINUE
  200 CONTINUE
      IF(NVDISP.EQ.0) GO TO 300
      DO 250 I=1,NVDISP
      VPT(I) = 0.0
  250 CONTINUE
  300 CONTINUE
      IF(NWDISP.EQ.0) GO TO 400
      DO 350 I=1,NWDISP
      WPT(I) = 0.0
  350 CONTINUE
  400 CONTINUE
      RETURN
      END
      SUBROUTINE PNTOUT(IOUT,NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
C *** FOR PRINTED OUTPUT OF INFORMATION IN BLANK COMMON - ZZZ
C *** CALLED BY PSAP1
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)
      DIMENSION NODE(20)
      GO TO (1000,2000), IOUT
 1000 CONTINUE
C
C *** FOR OUTPUT OF GEOMETRY INFORMATION
C
```

```
      WRITE(6,16)                                                       INIT1930
   16 FORMAT(///,5X,'GRID POINT INFORMATION',///)                       INIT1940
      WRITE(6,17)                                                       INIT1950
   17 FORMAT(5X,'RESEQUENCED',4X,'USER INPUT'/                          INIT1960
     15X,'GRID POINT',5X,'GRID POINT'/                                  INIT1970
     25X,'NUMBER',9X,'NUMBER',13X,'X',14X,'Y',14X,'Z'//)                INIT1980
      DO 30 I=1,NNODE                                                   INIT1990
      WRITE(6,18) I,NUMPT(I),XPT(I),YPT(I),ZPT(I)                       INIT2000
   18 FORMAT(2X,I10,5X,I10,3X,3E15.4)                                   INIT2010
   30 CONTINUE                                                          INIT2020
      WRITE(6,19)                                                       INIT2030
   19 FORMAT(///,5X,'ELEMENT INFORMATION - WITH RESEQUENCED GRID POINTS INIT2040
     1'///)                                                             INIT2050
      WRITE (6,9008)                                                    INIT2060
 9008 FORMAT(1X,'RESEQUENCED',4X,'USER INPUT',25X,'GRID POINTS'/        INIT2070
     11X,'ELEMENT',8X,'ELEMENT'/                                        INIT2080
     21X,'NUMBER',9X,'NUMBER',7X,'     1    2    3    4    5    6    7 INIT2090
     3 8    9   10   11   12   13   14   15   16   17   18   19   20'//)INIT2100
      REWIND 10                                                         INIT2110
      I = 0                                                             INIT2120
   35 CONTINUE                                                          INIT2130
      I = I+1                                                           INIT2140
      READ(10,END=999) NEND,NUMEL,(NODE(J),J=1,NEND)                    INIT2150
      IF(NEND.EQ.12) GO TO 40                                           INIT2160
      WRITE(6,9010) I,NUMEL,(NODE(J),J=1,NEND)                          INIT2170
 9010 FORMAT(1X,I4,11X,I4,9X,20I5)                                      INIT2180
      GO TO 35                                                          INIT2190
   40 WRITE(6,9010) I,NUMEL,(NODE(J),J=1,4),(NODE(J),J=9,12)            INIT2200
      GO TO 35                                                          INIT2210
 2000 CONTINUE                                                          INIT2220
C                                                                       INIT2230
C *** FOR OUTPUT OF DISPLACEMENT DATA                                   INIT2240
C                                                                       INIT2250
      WRITE(6,210)                                                      INIT2260
  210 FORMAT(///,5X,'DISPLACEMENTS TO BE PLOTTED',///)                  INIT2270
      WRITE(6,17)                                                       INIT2280
      DO 230 I=1,NNODE                                                  INIT2290
      U = 0.0                                                           INIT2300
      IF(NUDISP.NE.0) U = UPT(I)                                        INIT2310
      V = 0.0                                                           INIT2320
      IF(NVDISP.NE.0) V = VPT(I)                                        INIT2330
      W = 0.0                                                           INIT2340
      IF(NWDISP.NE.0) W = WPT(I)                                        INIT2350
      WRITE(6,18) I,NUMPT(I),U,V,W                                      INIT2360
  230 CONTINUE                                                          INIT2370
  999 RETURN                                                            INIT2380
      END                                                               INIT2390
      SUBROUTINE ELTYPE(MTYPE,KGEOM)                                    ELER0010
```

```
C                                                                        ELER0020
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  ELER0030
C                                                                        ELER0040
C                                                                        ELER0050
C ***THIS SUBROUTINE CALLS OTHER ROUTINES TO READ ELEMENT CONNECTIVITY   ELER0060
C *** MTYPE = ELEMENT TYPE                                               ELER0070
C *** KGEOM = 1    -    ADINA ELEMENTS                                   ELER0080
C *** KGEOM = 2    -    NONSAP ELEMENTS                                  ELER0090
C *** KGEOM = 9    -    SAP IV ELEMENTS                                  ELER0100
C *** CALLED BY GEOM1/GEOM2/GEOM9/                                       ELER0110
C                                                                        ELER0120
C                                                                        ELER0130
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  ELER0140
C                                                                        ELER0150
      IF(KGEOM.EQ.1) GO TO 20                                            ELER0160
      IF(KGEOM.EQ.2) GO TO 40                                            ELER0170
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12),MTYPE                           ELER0180
    1 CALL TRUSS                                                         ELER0190
      GO TO 900                                                          ELER0200
    2 CALL BEAM                                                          ELER0210
      GO TO 900                                                          ELER0220
    3 CALL PLANE                                                         ELER0230
      GO TO 900                                                          ELER0240
    4 CALL PLANE                                                         ELER0250
      GO TO 900                                                          ELER0260
    5 CALL THREED                                                        ELER0270
      GO TO 900                                                          ELER0280
    6 CALL SHELL                                                         ELER0290
      GO TO 900                                                          ELER0300
    7 CALL BNDRY                                                         ELER0310
      GO TO 900                                                          ELER0320
    8 CALL SOL21                                                         ELER0330
      GO TO 900                                                          ELER0340
    9 CALL ERROR(1)                                                      ELER0350
      GO TO 900                                                          ELER0360
   10 CALL ERROR(1)                                                      ELER0370
      GO TO 900                                                          ELER0380
   11 CALL ERROR(1)                                                      ELER0390
      GO TO 900                                                          ELER0400
   12 CALL ERROR(1)                                                      ELER0410
      GO TO 900                                                          ELER0420
   20 CONTINUE                                                           ELER0430
      GO TO (21,22,23,24),MTYPE                                          ELER0440
   21 CALL ADTRUS                                                        ELER0450
      GO TO 900                                                          ELER0460
   22 CALL ADPLAN                                                        ELER0470
      GO TO 900                                                          ELER0480
   23 CALL AD3DEE                                                        ELER0490
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      GO TO 900                                                         ELER0500
   24 CALL ADBEAM                                                       ELER0510
      GO TO 900                                                         ELER0520
   40 CONTINUE                                                          ELER0530
      GO TO (41,42,43),MTYPE                                            ELER0540
   41 CALL NSTRUS                                                       ELER0550
      GO TO 900                                                         ELER0560
   42 CALL NSPLAN                                                       ELER0570
      GO TO 900                                                         ELER0580
   43 CALL NS3DEE                                                       ELER0590
  900 RETURN                                                            ELER0600
      END                                                               ELER0610
      SUBROUTINE ERROR(N)                                               ELER0620
C                                                                       ELER0630
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  ELER0640
C                                                                       ELER0650
C *** THIS SUBROUTINE TERMINATES THE PROGRAM DUE TO ERROR IN INPUT.     ELER0660
C *** ERROR ALSO ZEROS AND ADVANCES THE CALCOMP PLOTTER                 ELER0670
C *** CALLED BY ELTYPE/PSAP1/INITAL/PLOTX/THREED/SOL21/ADTRUS/ADPLAN/   ELER0680
C *** AD3DEE/ADBEAM/NSTRUS/NSPLAN/NS3DEE/GEOM2/                         ELER0690
C                                                                       ELER0700
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  ELER0710
C                                                                       ELER0720
      COMMON/CORGN/ YPMAX,YSPACE,PSIZE                                  ELER0730
      CALL CALPLT(0.0,YPMAX+6.0,-3)                                     ELER0740
      GO TO(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20),N       ELER0750
    1 CONTINUE                                                          ELER0760
      WRITE(6,9001)                                                     ELER0770
 9001 FORMAT(///,1X,'TERMINATION OCCURRED IN SUBROUTINE ELTYPE   ELEMENTELER0780
     1 IN INPUT DATA CANNOT BE PLOTTED  CHECK ELEMENT TYPES'///)        ELER0790
      GO TO 1000                                                        ELER0800
    2 CONTINUE                                                          ELER0810
      WRITE(6,9002)                                                     ELER0820
 9002 FORMAT(///,1X,'ABNORMAL TERMINATION OCCURRED IN SUBROUTINE PSAP1 CELER0830
     1HECK VALUE OF KODE IN NAMELIST PICT'///)                          ELER0840
      GO TO 1000                                                        ELER0850
    3 CONTINUE                                                          ELER0860
      WRITE(6,9003)                                                     ELER0870
 9003 FORMAT(///,1X,'ABNORMAL TERMINATION OCCURRED IN SUBROUTINE INITAL ELER0880
     1- ATTEMPT TO READ NAMELIST OPTION'///)                            ELER0890
      GO TO 1000                                                        ELER0900
    4 CONTINUE                                                          ELER0910
      WRITE(6,9004)                                                     ELER0920
 9004 FORMAT(//,1X,'ABNORMAL TERMINATION OCCURRED IN PLOTX'//)          ELER0930
      GO TO 1000                                                        ELER0940
    5 CONTINUE                                                          ELER0950
      WRITE(6,9005)                                                     ELER0960
 9005 FORMAT(/,1X,'ABNORMAL TERMINATION IN THREFD,ELEMENT CARD ERROR'/) ELER0970
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```
      GO TO 1000                                                        ELER0980
    6 CONTINUE                                                          ELER0990
      WRITE(6,9006)                                                     ELER1000
 9006 FORMAT(/,1X,'ABNORMAL TERMINATION IN SOL21 ,ELEMENT CARD ERROR'/) ELER1010
      GO TO 1000                                                        ELER1020
    7 CONTINUE                                                          ELER1030
      WRITE(6,9007)                                                     ELER1040
 9007 FORMAT(/,1X,'ABNORMAL TERMINATION IN ADTRUS,ELEMENT CARD ERROR'/) ELER1050
      GO TO 1000                                                        ELER1060
    8 CONTINUE                                                          ELER1070
      WRITE(6,9008)                                                     ELER1080
 9008 FORMAT(/,1X,'ABNORMAL TERMINATION IN ADPLAN,ELEMENT CARD ERROR'/) ELER1090
      GO TO 1000                                                        ELER1100
    9 CONTINUE                                                          ELER1110
      WRITE(6,9009)                                                     ELER1120
 9009 FORMAT(/,1X,'ABNORMAL TERMINATION IN AD3DEE,ELEMENT CARD ERROR'/) ELER1130
      GO TO 1000                                                        ELER1140
   10 CONTINUE                                                          ELER1150
      WRITE(6,9010)                                                     ELER1160
 9010 FORMAT(/,1X,'ABNORMAL TERMINATION IN ADBEAM,ELEMENT CARD ERROR'/) ELER1170
      GO TO 1000                                                        ELER1180
   11 CONTINUE                                                          ELER1190
      WRITE(6,9011)                                                     ELER1200
 9011 FORMAT(/,1X,'ABNORMAL TERMINATION IN NSTRUS,ELEMENT CARD ERROR'/) ELER1210
      GO TO 1000                                                        ELER1220
   12 CONTINUE                                                          ELER1230
      WRITE(6,9012)                                                     ELER1240
 9012 FORMAT(/,1X,'ABNORMAL TERMINATION IN NSPLAN,ELEMENT CARD ERROR'/) ELER1250
      GO TO 1000                                                        ELER1260
   13 CONTINUE                                                          ELER1270
      WRITE(6,9013)                                                     ELER1280
 9013 FORMAT(/,1X,'ABNORMAL TERMINATION IN NS3DEE,ELEMENT CARD ERROR'/) ELER1290
      GO TO 1000                                                        ELER1300
   14 CONTINUE                                                          ELER1310
      WRITE(6,9014)                                                     ELER1320
 9014 FORMAT(/,1X,'ABNORMAL TERMINATION NONSAP MESH CANNOT BE PLOTTED'/)ELER1330
      GO TO 1000                                                        ELER1340
   15 CONTINUE                                                          ELER1350
      GO TO 1000                                                        ELER1360
   16 CONTINUE                                                          ELER1370
      GO TO 1000                                                        ELER1380
   17 CONTINUE                                                          ELER1390
      GO TO 1000                                                        ELER1400
   18 CONTINUE                                                          ELER1410
      GO TO 1000                                                        ELER1420
   19 CONTINUE                                                          ELER1430
      GO TO 1000                                                        ELER1440
   20 CONTINUE                                                          ELER1450
```

```
 1000 CONTINUE                                                           ELER1460
      CALL PSTOP                                                         ELER1470
      RETURN                                                             ELER1480
      END                                                                ELER1490
      SUBROUTINE GEOM9(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                    SAPF0010
C                                                                        SAPF0020
C  *     *     *     *     *     *     *     *     *     *     *     *   SAPF0030
C                                                                        SAPF0040
C *** GEOM9 READS SAP IV GEOMETRY DATA                                   SAPF0050
C *** CALLED BY PSAP1                                                    SAPF0060
C                                                                        SAPF0070
C  *     *     *     *     *     *     *     *     *     *     *     *   SAPF0080
C                                                                        SAPF0090
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,  SAPF0100
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,         SAPF0110
     2PSCALE,KDISP,DMAG,KODE                                             SAPF0120
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP                    SAPF0130
      COMMON/GCONT/NJMNP,NPAR(20),NELTYP,NJMEL                           SAPF0140
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)       SAPF0150
      DATA CTEST/'C    '/                                                SAPF0160
C                                                                        SAPF0170
C *** INSERT ROUTINE HERE                                                SAPF0180
C                                                                        SAPF0190
      READ(5,100) HED                                                    SAPF0200
  100 FORMAT(12A6)                                                       SAPF0210
C                                                                        SAPF0220
C                                                                        SAPF0230
C *** READ MASTER CONTROL CARD                                           SAPF0240
C *** NUMNP = TOTAL NUMBER OF NODE POINTS                                SAPF0250
C *** NELTYP = NUMBER OF ELEMENT GROUPS                                  SAPF0260
C                                                                        SAPF0270
C                                                                        SAPF0280
      READ(5,200)NUMNP,NELTYP                                            SAPF0290
  200 FORMAT(2I5)                                                        SAPF0300
      NNODE=NUMNP                                                        SAPF0310
C                                                                        SAPF0320
C*********READ OR GENERATE NODAL POINT DATA                              SAPF0330
C                                                                        SAPF0340
      NOLD=0                                                             SAPF0350
   10 READ(5,9006) CT,N,XPT(N),YPT(N),ZPT(N),KN                          SAPF0360
 9006 FORMAT(A1,I4,30X,3F10.0,I5)                                        SAPF0370
C                                                                        SAPF0380
C ***CHECK FOR CYLINDRICAL COORDINATES                                   SAPF0390
C                                                                        SAPF0400
      IF(CT.NE.CTEST) GO TO 20                                           SAPF0410
         R=XPT(N)                                                        SAPF0420
         XPT(N)=R*SIN(ZPT(N)/57.2958)                                    SAPF0430
         ZPT(N)=R*COS(ZPT(N)/57.2958)                                    SAPF0440
```

```
   20 CONTINUE                                                         SAPF0450
      NUMPT(N)=N                                                       SAPF0460
      IF (NOLD.EQ.0) GO TO 50                                          SAPF0470
C                                                                      SAPF0480
C*********CHECK IF GENERATION IS REQUIRED                               SAPF0490
C                                                                      SAPF0500
      IF (KN.EQ.0) GO TO 50                                            SAPF0510
      NUM=(N-NOLD)/KN                                                  SAPF0520
      NUMN=NUM-1                                                       SAPF0530
      IF(NUMN.LT.1) GO TO 50                                           SAPF0540
      XNUM=NUM                                                         SAPF0550
      DX=(XPT(N)-XPT(NOLD))/XNUM                                       SAPF0560
      DY=(YPT(N)-YPT(NOLD))/XNUM                                       SAPF0570
      DZ=(ZPT(N)-ZPT(NOLD))/XNUM                                       SAPF0580
      K=NOLD                                                           SAPF0590
      DO 30 J=1,NUMN                                                   SAPF0600
      KK=K                                                             SAPF0610
      K=K+KN                                                           SAPF0620
      XPT(K)=XPT(KK)+DX                                                SAPF0630
      YPT(K)=YPT(KK)+DY                                                SAPF0640
      ZPT(K)=ZPT(KK)+DZ                                                SAPF0650
      NUMPT(K)=K                                                       SAPF0660
   30 CONTINUE                                                         SAPF0670
   50 NOLD=N                                                           SAPF0680
      IF(N.NE.NUMNP) GO TO 10                                          SAPF0690
      NUMEL=0                                                          SAPF0700
C********* READ ELEMENT CONTROL CARDS                                   SAPF0710
      DO 900 M=1,NELTYP                                                SAPF0720
      READ(5,1001,END=999) (NPAR(I),I=1,14)                            SAPF0730
 1001 FORMAT(14I5)                                                     SAPF0740
      WRITE(6,9010) (NPAR(I),I=1,14)                                   SAPF0750
 9010 FORMAT(///,'  NPAR = ',20I5///)                                  SAPF0760
      MTYPE=NPAR(1)                                                    SAPF0770
      CALL ELTYPE(MTYPE,KGEOM)                                         SAPF0780
  900 CONTINUE                                                         SAPF0790
      ENDFILE 10                                                       SAPF0800
  999 RETURN                                                           SAPF0810
      END                                                              SAPF0820
      SUBROUTINE TRUSS                                                 SAPF0830
C                                                                      SAPF0840
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF0850
C                                                                      SAPF0860
C *** READS SAP IV TRUSS ELEMENT CARDS (ELTYPE 1)                      SAPF0870
C                                                                      SAPF0880
C *** CALLED BY ELTYPE                                                 SAPF0890
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF0900
C                                                                      SAPF0910
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                         SAPF0920
```

```
      N2=2                                                              SAPF0930
      NUME=NPAR(2)                                                      SAPF0940
      NUMMAT=NPAR(3)                                                    SAPF0950
C ****  READ MATERIAL PROPERTY CARDS (DUMMY)                            SAPF0960
      DO 10 I=1,NUMMAT                                                  SAPF0970
      READ(5,1001) DUMMY                                                SAPF0980
 1001 FORMAT(10A8)                                                      SAPF0990
   10 CONTINUE                                                          SAPF1000
C ***** READ ELEMENT LOAD MUL. (DUMMY1)                                 SAPF1010
      DO 20 I=1,4                                                       SAPF1020
      READ(5,1001) DUMMY1                                               SAPF1030
   20 CONTINUE                                                          SAPF1040
      IF(NPAR(14).EQ.0) NPAR(14) = 1                                    SAPF1050
      N= NPAR(14)                                                       SAPF1060
C *** READ ELEMENT CONNECTION INFORMATION OR GENERATE                   SAPF1070
  100 READ(5,1004) M,II,JJ,MTYP,TEM,KK                                  SAPF1080
 1004 FORMAT(4I5,F10.0,I5)                                              SAPF1090
      IF(KK.EQ.0) KK=1                                                  SAPF1100
  120 IF (M.NE.N) GO TO 200                                             SAPF1110
      I=II                                                              SAPF1120
      J=JJ                                                              SAPF1130
      KKK=KK                                                            SAPF1140
  200 CONTINUE                                                          SAPF1150
      NUMEL=NUMEL+1                                                     SAPF1160
      WRITE(10) N2,N,I,J                                                SAPF1170
      IF(N.EQ.NUME) RETURN                                              SAPF1180
      N=N+1                                                             SAPF1190
      I=I+KKK                                                           SAPF1200
      J=J+KKK                                                           SAPF1210
      IF(N.GT.M) GO TO 100                                              SAPF1220
      GO TO 120                                                         SAPF1230
      END                                                               SAPF1240
      SUBROUTINE PLANE                                                  SAPF1250
C                                                                       SAPF1260
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF1270
C                                                                       SAPF1280
C *** READS SAP IV MEMBRANE ELEMENT CARDS (ELTYPE 3)                    SAPF1290
C *** CALLED BY ELTYPE                                                  SAPF1300
C                                                                       SAPF1310
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF1320
C                                                                       SAPF1330
      DIMENSION  EMUL(4,5),IE(5),IX(4)                                  SAPF1340
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                          SAPF1350
      N4=4                                                              SAPF1360
      NUME= NPAR(2)                                                     SAPF1370
      NUMMAT= NPAR(3)                                                   SAPF1380
C ****  READ MATERIAL PROPERTIES                                        SAPF1390
      DO 60 M=1,NUMMAT                                                  SAPF1400
```

```
      READ(5,1010) MAT,NT                                                SAPF1410
 1010 FORMAT(2I5)                                                        SAPF1420
      IF(NT.EQ.0) NT=1                                                   SAPF1430
      NTC=2* NT                                                          SAPF1440
      DO 50 K=1,NTC                                                      SAPF1450
      READ(5,1005) DUMMY                                                 SAPF1460
 1005 FORMAT (10A8)                                                      SAPF1470
   50 CONTINUE                                                           SAPF1480
   60 CONTINUE                                                           SAPF1490
C                                                                        SAPF1500
C****  READ ELEMENT LOAD FACTORS                                         SAPF1510
C                                                                        SAPF1520
      READ(5,1002) ((EMUL(I,J),J=1,5),I=1,4)                             SAPF1530
 1002 FORMAT(5F10.0)                                                     SAPF1540
C                                                                        SAPF1550
C****  READ ELEMENT PROPERTIES                                           SAPF1560
C                                                                        SAPF1570
      IF(NPAR(14).EQ.0) NPAR(14) = 1                                     SAPF1580
      N=NPAR(14)-1                                                       SAPF1590
  130 READ(5,1003) M,(IE(I),I=1,4),KG                                    SAPF1600
 1003 FORMAT(5I5,30X,I5)                                                 SAPF1610
      IF(KG.EQ.0) KG=1                                                   SAPF1620
  140 N=N+1                                                              SAPF1630
      IF(M.EQ.N) GO TO 145                                               SAPF1640
      DO 142 I=1,4                                                       SAPF1650
  142 IX(I)=IX(I)+KG                                                     SAPF1660
      GO TO 150                                                          SAPF1670
  145 DO 148 I=1,4                                                       SAPF1680
  148 IX(I)=IE(I)                                                        SAPF1690
  150 CONTINUE                                                           SAPF1700
      I = IX(1)                                                          SAPF1710
      J = IX(2)                                                          SAPF1720
      K = IX(3)                                                          SAPF1730
      L = IX(4)                                                          SAPF1740
      NUMEL=NUMEL+1                                                      SAPF1750
      WRITE(10) N4,N,I,J,K,L                                             SAPF1760
  310 IF(N.EQ.NUME) RETURN                                               SAPF1770
      IF(N.EQ.M) GO TO 130                                               SAPF1780
      GO TO 140                                                          SAPF1790
      END                                                                SAPF1800
      SUBROUTINE BEAM                                                    SAPF1810
C                                                                        SAPF1820
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF1830
C                                                                        SAPF1840
C *** READS SAP IV BEAM ELEMENT CARDS (ELTYPE 2)                         SAPF1850
C *** CALLED BY ELTYPE                                                   SAPF1860
C                                                                        SAPF1870
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF1880
```

```
C                                                                        SAPF1890
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                           SAPF1900
      N2=2                                                               SAPF1910
      NUME=NPAR(2)                                                       SAPF1920
      NUMEPC=NPAR(3)                                                     SAPF1930
      NUMFEF=NPAR(4) * 2                                                 SAPF1940
      NUMMAT=NPAR(5)                                                     SAPF1950
C ***  READ MATERIAL PROPERTY CARDS (DUMMY)                              SAPF1960
      DO 10  I=1,NUMMAT                                                  SAPF1970
      READ(5,1001) DUMMY                                                 SAPF1980
 1001 FORMAT(10A8)                                                       SAPF1990
   10 CONTINUE                                                           SAPF2000
C ***  READ ELEMENT PROPERTY CARDS (DUMMY1)                              SAPF2010
      DO 20  J=1,NUMEPC                                                  SAPF2020
      READ (5,1001) DUMMY1                                               SAPF2030
   20 CONTINUE                                                           SAPF2040
C ***  READ ELEMENT LOAD MULTIPLIERS(DUMMY2)                             SAPF2050
      DO 30 K=1,3                                                        SAPF2060
      READ (5,1001) DUMMY2                                               SAPF2070
   30 CONTINUE                                                           SAPF2080
C ***  READ  FIXED-END FORCE CARDS(DUMMY3)                               SAPF2090
      DO 40 L=1,NUMFEF                                                   SAPF2100
      READ(5,1001) DUMMY3                                                SAPF2110
   40 CONTINUE                                                           SAPF2120
      IF(NPAR(14).EQ.0) NPAR(14) = 1                                     SAPF2130
      N=NPAR(14)                                                         SAPF2140
C ***  READ ELEMENT CONNECTION  INFO                                     SAPF2150
  100 READ(5,1002) M,II,JJ ,KK                                           SAPF2160
 1002 FORMAT(3I5,47X,I8)                                                 SAPF2170
      IF (KK.EQ.0) KK=1                                                  SAPF2180
  120 IF (M.NE.N) GO TO 200                                              SAPF2190
      I = II                                                             SAPF2200
      J = JJ                                                             SAPF2210
      KKK = KK                                                           SAPF2220
  200 CONTINUE                                                           SAPF2230
      NUMEL = NUMEL+1                                                    SAPF2240
      WRITE(10) N2,N,I,J                                                 SAPF2250
      IF (N.EQ.NUME) RETURN                                              SAPF2260
      N = N + 1                                                          SAPF2270
      I = I + KKK                                                        SAPF2280
      J = J + KKK                                                        SAPF2290
      IF (N.GT.M) GO TO 100                                              SAPF2300
      GO TO 120                                                          SAPF2310
      END                                                                SAPF2320
      SUBROUTINE THREED                                                  SAPF2330
C                                                                        SAPF2340
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  SAPF2350
C                                                                        SAPF2360
```

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C *** THIS SUBROUTINE READS SAP IV 3-D 8 NODE BRICK ELEMENTS           SAPF2370
C *** CALLED BY ELTYPE                                                  SAPF2380
C                                                                      SAPF2390
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * SAPF2400
C                                                                      SAPF2410
      DIMENSION INP(8),NP(8)                                           SAPF2420
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                         SAPF2430
      N8=8                                                             SAPF2440
      NUME=NPAR(2)                                                     SAPF2450
      NUMMAT=NPAR(3)                                                   SAPF2460
      NDISLD=NPAR(4)                                                   SAPF2470
C *** READ THE MATERIAL PROPERTIES                                      SAPF2480
      DO 50 M=1,NUMMAT                                                 SAPF2490
          READ(5,9002) DUMMY                                           SAPF2500
 9002 FORMAT(20A4)                                                     SAPF2510
   50     CONTINUE                                                     SAPF2520
C *** READ DISTRIBUTED SURFACE LOADS                                    SAPF2530
      IF(NDISLD.EQ.0) GO TO 61                                         SAPF2540
      DO 60 M=1,NDISLD                                                 SAPF2550
          READ(5,9002) DUMMY                                           SAPF2560
   60     CONTINUE                                                     SAPF2570
   61 CONTINUE                                                         SAPF2580
C *** READ ACCELERATION DUE TO GRAVITY                                  SAPF2590
      READ(5,9002) DUMMY                                               SAPF2600
C *** READ ELEMENT LOAD CASE MULTIPLIERS                                SAPF2610
      DO 80 I=1,5                                                      SAPF2620
          READ(5,9002) DUMMY                                           SAPF2630
   80 CONTINUE                                                         SAPF2640
      IF(NPAR(14).EQ.0) NPAR(14)=1                                     SAPF2650
      NEL=NPAR(14)-1                                                   SAPF2660
  130 READ(5,9006) INEL,(INP(I),I=1,8),ININT,IMAT,IINC                  SAPF2670
 9006 FORMAT(12I5)                                                     SAPF2680
      IF(IINC.EQ.0) IINC=1                                             SAPF2690
  140 NEL=NEL+1                                                        SAPF2700
      ML=INEL-NEL                                                      SAPF2710
      IF(ML)150,155,160                                                SAPF2720
  150 CALL ERROR(5)                                                    SAPF2730
C *** NO GENERATION OF NODE POINTS REQUIRED                             SAPF2740
  155 DO 156 I=1,8                                                     SAPF2750
          NP(I)=INP(I)                                                 SAPF2760
  156     CONTINUE                                                     SAPF2770
      GO TO 162                                                        SAPF2780
C *** GENERATION REQUIRED                                               SAPF2790
  160 DO 161 I=1,8                                                     SAPF2800
          NP(I)=NP(I)+IINC                                             SAPF2810
  161     CONTINUE                                                     SAPF2820
  162 CONTINUE                                                         SAPF2830
      NUMEL=NUMEL+1                                                    SAPF2840
```

```
      WRITE(10) N8,NEL,(NP(I),I=1,8)                                    SAPF2850
      IF(NEL.EQ.NUME) RETURN                                            SAPF2860
      IF(NEL.EQ.INEL) GO TO 130                                         SAPF2870
      GO TO 140                                                         SAPF2880
      END                                                               SAPF2890
      SUBROUTINE SHELL                                                  SAPF2900
C                                                                       SAPF2910
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * SAPF2920
C                                                                       SAPF2930
C *** READS SAP IV SHELL ELEMENT CARDS (ELTYPE 6)                       SAPF2940
C *** CALLED BY ELTYPE                                                  SAPF2950
C                                                                       SAPF2960
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * SAPF2970
C                                                                       SAPF2980
      DIMENSION IY(7),IX(4)                                             SAPF2990
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NJMEL                          SAPF3000
      N4=4                                                              SAPF3010
      ISTOP=0                                                           SAPF3020
      NUME = NPAR(2)                                                    SAPF3030
      NUMMAT = NPAR(3)                                                  SAPF3040
      NMAT= 2*NUMMAT                                                    SAPF3050
C *** READ MATERIAL PROPERTIES (DUMMY)                                  SAPF3060
      DO 10 N=1,NMAT                                                    SAPF3070
      READ(5,1000) DUMMY                                                SAPF3080
C                                                                       SAPF3090
 1000 FORMAT(10A8)                                                      SAPF3100
   10 CONTINUE                                                          SAPF3110
C **** READ ELEMENT LOAD FACTORS (DUMMY1)                               SAPF3120
      DO 20 K=1,5                                                       SAPF3130
      READ(5,1000) DUMMY1                                               SAPF3140
   20 CONTINUE                                                          SAPF3150
      IF(NPAR(14).EQ.0) NPAR(14) = 1                                    SAPF3160
      NN = NPAR(14)-1                                                   SAPF3170
  100 READ(5,1001) MM,IY                                                SAPF3180
 1001 FORMAT(8I5)                                                       SAPF3190
  110 NN = NN + 1                                                       SAPF3200
      IF (MM -NN) 440,50,60                                             SAPF3210
   50 DO 45  I=1,7                                                      SAPF3220
   45 IX(I) = IY(I)                                                     SAPF3230
      INCL = IY(7)                                                      SAPF3240
      IF (INCL.EQ.0)  INCL=1                                            SAPF3250
      GO TO 70                                                          SAPF3260
   60 DO 65  I=1,4                                                      SAPF3270
   65 IX(I)= IX(I) + INCL                                               SAPF3280
   70 CONTINUE                                                          SAPF3290
      I=IX(1)                                                           SAPF3300
      J= IX(2)                                                          SAPF3310
      K=IX(3)                                                           SAPF3320
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      L=IX(4)                                                           SAPF3330
      NUMEL = NUMEL +1                                                  SAPF3340
      WRITE(10) N4,NV,I,J,K,L                                           SAPF3350
      GO TO 500                                                         SAPF3360
  440 WRITE (6,2005) MM                                                 SAPF3370
 2005 FORMAT(19HOCARD FOR ELEMT(,I5,14H) IS IN ERROR.,1X)               SAPF3380
      ISTOP = 1                                                         SAPF3390
  500 IF(NN.LT.MM) GO TO 110                                            SAPF3400
      IF(NN.EQ.NUME) RETURN                                             SAPF3410
      IF(ISTOP.EQ.1) STOP                                               SAPF3420
      GO TO 100                                                         SAPF3430
      END                                                               SAPF3440
      SUBROUTINE BNDRY                                                  SAPF3450
C                                                                       SAPF3460
C *     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF3470
C                                                                       SAPF3480
C *** READS SAP IV BOUNDARY ELEMENT CARDS (ELTYPE 7)                    SAPF3490
C *** BOUNDARY ELEMENTS ARE NOT PLOTTED                                 SAPF3500
C *** CALLED BY ELTYPE                                                  SAPF3510
C                                                                       SAPF3520
C *     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF3530
C                                                                       SAPF3540
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                          SAPF3550
      NUME=NPAR(2)                                                      SAPF3560
C *** READ LOAD CASE CARD (DUMMY)                                       SAPF3570
      READ(5,1002) DUMMY                                                SAPF3580
 1002 FORMAT(10A8)                                                      SAPF3590
C *** READ BOUNDARY ELEMENT CARDS                                       SAPF3600
      N=0                                                               SAPF3610
  100 READ(5,1004) M,II,KK                                              SAPF3620
      N=N+1                                                             SAPF3630
      IF(N.GE.NUME) RETURN                                              SAPF3640
      IF(KK.GT.0) GO TO 200                                             SAPF3650
      GO TO 100                                                         SAPF3660
  200 READ(5,1004) M2,II2,KK2                                           SAPF3670
      N=N+(M2-M)/KK                                                     SAPF3680
      IF(N.GE.NUME) RETURN                                              SAPF3690
      GO TO 100                                                         SAPF3700
 1004 FORMAT(2I5,25X,I5)                                                SAPF3710
      END                                                               SAPF3720
      SUBROUTINE SOL21                                                  SAPF3730
C                                                                       SAPF3740
C *     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF3750
C                                                                       SAPF3760
C *** THIS SUBROUTINE READS SAP IV 3-D,8-20 NODE BRICK ELEMENTS         SAPF3770
C *** CALLED BY ELTYPE                                                  SAPF3780
C                                                                       SAPF3790
C *     *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *  SAPF3800
```

```
C
      DIMENSION NP(20),INP(20)
      COMMON/GCONT/NJMNP,NPAR(20),NELTYP,NUMEL
      N20=20
      NSOL21=NPAR(2)
      NUMMAT=NPAR(3)
      MAXTP=NPAR(4)
      IF(MAXTP.EQ.0) MAXTP=1
      NORTHO=NPAR(5)
      NDLS=NPAR(6)
      MAXNOD=NPAR(7)
      IF(MAXNOD.EQ.0) MAXNOD=21
      IF(MAXNOD.EQ.8) N20=8
      NOPSET=NPAR(8)
C *** READ THE MATERIAL PROPERTY CARDS
      DO 50 J=1,NUMMAT
         READ(5,9002) M,NTP
 9002 FORMAT(2I5)
         IF(NTP.EQ.0) NTP=1
         NTP2=2*NTP
         DO 40 JJ=1,NTP2
            READ(5,9004) DUMMY
 9004 FORMAT(20A4)
   40       CONTINUE
   50    CONTINUE
C *** READ MATERIAL AXES ORIENTATION SETS
      IF(NORTHO.EQ.0) GO TO 61
      DO 60 J=1,NORTHO
         READ(5,9004) DUMMY
   60    CONTINUE
   61 CONTINUE
C *** READ DISTRIBUTED SURFACE LOAD DATA
      IF(NDLS.EQ.0) GO TO 71
      NDLS2=NDLS*2
      DO 70 J=1,NDLS2
         READ(5,9004) DUMMY
   70    CONTINUE
   71 CONTINUE
C *** READ STRESS OUTPUT LOCATION SETS
      IF(NOPSET.EQ.0) GO TO 81
      DO 80 J=1,NOPSET
         READ(5,9004) DUMMY
   80    CONTINUE
   81 CONTINUE
C *** READ ELEMENT LOAD CASE MULTIPLIERS
      DO 90 J=1,5
         READ(5,9004) DUMMY
   90    CONTINUE
```

```
C *** READ ELEMENT DATA CARDS                                           SAPF4290
      IF(NPAR(14).EQ.0) NPAR(14)=1                                      SAPF4300
      NEL=NPAR(14)-1                                                    SAPF4310
  130 READ(5,9006) INEL,IINC                                            SAPF4320
 9006 FORMAT(I5,35X,I5)                                                 SAPF4330
      READ(5,9008) (INP(I),I=1,N20)                                     SAPF4340
 9008 FORMAT(16I5)                                                      SAPF4350
      IF(IINC.EQ.0) IINC=1                                              SAPF4360
  140 NEL=NEL+1                                                         SAPF4370
      ML=INEL-NEL                                                       SAPF4380
      IF(ML) 150,155,160                                                SAPF4390
  150 CALL ERROR(6)                                                     SAPF4400
C *** NO GENERATION OF NODE POINTS REQUIRED                             SAPF4410
  155 DO 156 I=1,N20                                                    SAPF4420
         NP(I)=INP(I)                                                   SAPF4430
  156    CONTINUE                                                       SAPF4440
      GO TO 162                                                         SAPF4450
C *** GENERATION OF NODE POINTS REQUIRED                                SAPF4460
  160 DO 161 I=1,N20                                                    SAPF4470
         IF(NP(I).EQ.0) GO TO 161                                       SAPF4480
         NP(I)=NP(I)+KN                                                 SAPF4490
  161    CONTINUE                                                       SAPF4500
  162 CONTINUE                                                          SAPF4510
      NUMEL=NUMEL+1                                                     SAPF4520
      WRITE(10) N20,NEL,(NP(I),I=1,N20)                                 SAPF4530
      IF(NEL.EQ.NSOL21) RETURN                                          SAPF4540
      IF(NEL.LT.INEL) GO TO 140                                         SAPF4550
      KN=IINC                                                           SAPF4560
      GO TO 130                                                         SAPF4570
      END                                                               SAPF4580
      SUBROUTINE GEOM1(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                   ADNA0010
C                                                                       ADNA0020
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * ADNA0030
C                                                                       ADNA0040
C *** THIS ROUTINE READS ADINA DATA CARDS FROM THE TITLE CARD TO THE    ADNA0050
C *** ELEMENT CONTROL CARDS - IT IS CALLED BY PSAP1                     ADNA0060
C                                                                       ADNA0070
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * ADNA0080
C                                                                       ADNA0090
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT, ADNA0100
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,        ADNA0110
     2PSCALE,KDISP,DMAG,KODE                                            ADNA0120
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP                   ADNA0130
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                          ADNA0140
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)      ADNA0150
      DIMENSION IDOF(6),ID(6),IDOLD(6)                                  ADNA0160
     1,NODE(20)                                                         ADNA0170
      DATA CTEST/'X    '/                                               ADNA0180
```

```
      NCARD=0                                                           ADNA0190
      READ(5,9000) DUMMY                                                ADNA0200
 9000 FORMAT(20A4)                                                      ADNA0210
C *** READ MASTER CONTROL CARDS                                         ADNA0220
C *** NUMNP = TOTAL NUMBER OF NODE POINTS                               ADNA0230
C *** NELTYP = NUMBER OF ELEMENT GROUPS                                 ADNA0240
      READ(5,9001) NUMNP,(IDOF(I),I=1,6),NEGL,NEGNL,MODEX,NSTE          ADNA0250
 9001 FORMAT(I5,6I1,I4,3I5)                                             ADNA0260
      NELTYP=NEGL+NEGNL                                                 ADNA0270
      NNODE=NUMNP                                                       ADNA0280
      READ(5,9002) IMASS,IDAMP,IMASSN,IDAMPN                            ADNA0290
 9002 FORMAT(4I5)                                                       ADNA0300
      READ(5,9002) IEIG                                                 ADNA0310
      READ(5,9002) ISREF,NUMREF,IEQUIT,ITEMAX                           ADNA0320
      READ(5,9000) DUMMY                                                ADNA0330
      READ(5,9000) DUMMY                                                ADNA0340
      READ(5,9000) DUMMY                                                ADNA0350
C *** READ OR GENERATE NODAL POINT DATA                                 ADNA0360
      NOLD=0                                                            ADNA0370
      NEQ=0                                                             ADNA0380
   10 READ(5,9006)CT,N,(ID(I),I=1,6),XPT(N),YPT(N),ZPT(N),KN            ADNA0390
 9006 FORMAT(A1,I4,1X,I4,5I5,3F10.0,I5)                                 ADNA0400
C *** CHECK FOR CYLINDRICAL COORDINATES                                 ADNA0410
      IF(CT.NE.CTEST) GO TO 12                                          ADNA0420
         DUM=ZPT(N)/57.2958                                             ADNA0430
         R=YPT(N)                                                       ADNA0440
         YPT(N)=R*COS(ZPT(N)/57.2958)                                   ADNA0450
         ZPT(N)=R*SIN(ZPT(N)/57.2958)                                   ADNA0460
   12 CONTINUE                                                          ADNA0470
      NUMPT(N)=N                                                        ADNA0480
      IF(NOLD.EQ.0) GO TO 50                                            ADNA0490
C *** FOR GENERATION OF FIXED BOUNDARY CONDITIONS                       ADNA0500
      DO 15 I=1,6                                                       ADNA0510
      IF(IDOLD(I).EQ.-1.AND.ID(I).EQ.0) ID(I)=IDOLD(I)                  ADNA0520
   15    CONTINUE                                                       ADNA0530
      IF(KNOLD.EQ.0) GO TO 50                                           ADNA0540
      NUM=(N-NOLD)/KNOLD                                                ADNA0550
      NUMN=NUM-1                                                        ADNA0560
      IF(NUMN.LT.1) GO TO 50                                            ADNA0570
C *** TO COUNT DOFS TO DETERMINE NUMBER OF IC CARDS                     ADNA0580
      DO 20 I=1,6                                                       ADNA0590
         IF(IDOF(I).EQ.0.AND.IDOLD(I).EQ.0) NEQ=NEQ+NUMN                ADNA0600
   20 CONTINUE                                                          ADNA0610
      DX=(XPT(N)-XPT(NOLD))/NUM                                         ADNA0620
      IF(CT.NE.CTEST) GO TO 21                                          ADNA0630
      ROLD=YPT(NOLD)/COS(DUMOLD)                                        ADNA0640
      RNEW=YPT(N)/COS(DUM)                                              ADNA0650
      DR=(RNEW-ROLD)/NUM                                                ADNA0660
```

```
      DT=(DUM-DUMOLD)/NUM
      GO TO 22
   21 CONTINUE
      DY=(YPT(N)-YPT(NOLD))/NUM
      DZ=(ZPT(N)-ZPT(NOLD))/NUM
   22 CONTINUE
      K=NOLD
      DO 30 J=1,NUMN
         KK=K
         K=K+KNOLD
         XPT(K)=XPT(KK)+DX
          IF(CT.NE.CTEST) GO TO 26
          ROLD=ROLD+DR
          DUMOLD=DUMOLD+DT
          YPT(K)=ROLD*COS(DUMOLD)
          ZPT(K)=ROLD*SIN(DUMOLD)
          GO TO 28
   26     CONTINUE
         YPT(K)=YPT(KK)+DY
         ZPT(K)=ZPT(KK)+DZ
   28     CONTINUE
         NUMPT(K)=K
   30    CONTINUE
   50 NOLD=N
      KNOLD=KN
      DUMOLD=DUM
C *** TO COUNT DOFS TO DETERMINE NUMBER OF IC CARDS
      DO 55 I=1,6
          IF(IDOF(I).EQ.0.AND.ID(I).EQ.0) NEQ=NEQ+1
          IDOLD(I)=ID(I)
   55    CONTINUE
      IF(N.NE.NUMNP) GO TO 10
C *** READ LOAD CONTROL CARDS
      READ(5,9000) DUMMY
      DO 80 I=1,IMASSN
      IF(IMASSN.EQ.0) GO TO 81
         READ(5,9000) DUMMY
   80    CONTINUE
   81 CONTINUE
      IF(IDAMPN.EQ.0) GO TO 91
      DO 90 I=1,IDAMPN
         READ(5,9000) DUMMY
   90    CONTINUE
   91 CONTINUE
C *** READ INITIAL CONDITIONS
      READ(5,9002) ICON
      IF(ICON.EQ.0) GO TO 100
      CARDNR=NEQ/6.0
```

```
      NCARD=INT(CARDNR)                                                 ADNA1150
      TEST=CARDNR-NCARD                                                 ADNA1160
      IF(TEST.GT.0.1) NCARD=NCARD+1                                     ADNA1170
      DO 95 I=1,NCARD                                                   ADNA1180
         READ(5,9000) DUMMY                                             ADNA1190
   95    CONTINUE                                                       ADNA1200
      IF(IMASS.EQ.0) GO TO 100                                          ADNA1210
      DO 96 I=1,NCARD                                                   ADNA1220
         READ(5,9000) DUMMY                                             ADNA1230
   96    CONTINUE                                                       ADNA1240
      DO 98 I=1,NCARD                                                   ADNA1250
         READ(5,9000) DUMMY                                             ADNA1260
   98    CONTINUE                                                       ADNA1270
 9007 FORMAT(6E12.6)                                                    ADNA1280
  100 CONTINUE                                                          ADNA1290
      NUMEL=0                                                           ADNA1300
      WRITE(6,9009) NEQ,NCARD                                           ADNA1310
 9009 FORMAT(///,' NEQ AND NCARD FOR IC IN GEOM1  = ',I5,10X,I5///)     ADNA1320
C *** READ ELEMENT CONTROL CARDS                                        ADNA1330
      DO 900 M=1,NELTYP                                                 ADNA1340
          READ(5,9008,END=999)(NPAR(I),I=1,20)                          ADNA1350
      WRITE(6,9010) (NPAR(I),I=1,20)                                    ADNA1360
 9008 FORMAT(20I4)                                                      ADNA1370
 9010 FORMAT(///,'  NPAR = ',20I5///)                                   ADNA1380
          MTYPE=NPAR(1)                                                 ADNA1390
          CALL ELTYPE(MTYPE,KGEOM)                                      ADNA1400
  900     CONTINUE                                                      ADNA1410
      ENDFILE 10                                                        ADNA1420
  999 RETURN                                                            ADNA1430
      END                                                               ADNA1440
      SUBROUTINE ADTRUS                                                 ADNA1450
C                                                                       ADNA1460
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * ADNA1470
C                                                                       ADNA1480
C *** THIS SUBROUTINE TO READ ADINA TRUSS DATA                          ADNA1490
C *** THIS ROUTINE CALLED BY ELTYPE                                     ADNA1500
C                                                                       ADNA1510
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * ADNA1520
C                                                                       ADNA1530
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                          ADNA1540
      NUMMAT=NPAR(16)                                                   ADNA1550
      N2=2                                                              ADNA1560
      IF(NUMMAT.EQ.0) NUMMAT=1                                          ADNA1570
      IF(NPAR(15).EQ.1) NCARD=2                                         ADNA1580
      IF(NPAR(15).EQ.3) NCARD=3                                         ADNA1590
      IF(NPAR(15).NE.2) GO TO 20                                        ADNA1600
      CARDNR=NPAR(17)/8.0                                               ADNA1610
      NCARD=INT(CARDNR)                                                 ADNA1620
```

```
      TEST=CARDNR-NCARD
      IF(TEST.GT.0.1) NCARD=NCARD+1
      NCARD=NCARD+2
   20 CONTINUE
C *** READ MATERIAL PROPERTIES
      DO 50 J=1,NUMMAT
         DO 45 I=1,NCARD
            READ(5,9000) DUMMY
 9000 FORMAT(20A4)
   45       CONTINUE
   50    CONTINUE
C *** READ OR GENERATE ELEMENT DATA CARDS
      IF(NPAR(14).EQ.0) NPAR(14)=1
      NEL=NPAR(14)-1
  130 READ(5,9002) INEL,II,JJ,IINC
 9002 FORMAT(3I5,20X,I5)
      IF(IINC.EQ.0) IINC=1
  140 NEL=NEL+1
      ML=INEL-NEL
      IF(ML) 150,155,160
  150 CALL ERROR(7)
C *** NO GENERATION OF NODE POINTS REQUIRED
  155 I=II
      J=JJ
      GO TO 162
C *** GENERATION OF NODE POINTS REQUIRED
  160 I=I+KN
      J=J+KN
  162 CONTINUE
      NUMEL=NUMEL+1
      WRITE(10) N2,NEL,I,J
      IF(NEL.EQ.NPAR(2)) RETURN
      IF(NEL.LT.INEL) GO TO 140
      KN=IINC
      GO TO 130
      END
      SUBROUTINE ADPLAN
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL
      DIMENSION NP(12),INP(8)
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
C *** THIS SUBROUTINE TO READ ADINA 8-NODE PLANE ELEMENT DATA
C *** IT IS CALLED BY ELTYPE
C
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
```

```
      NUMMAT=NPAR(16)                                                   ADNA2110
      NSTRES=NPAR(13)                                                   ADNA2120
C *** CALCULATE THE NUMBER OF MATERIAL CASE CARDS                        ADNA2130
      IF(NPAR(15).EQ. 1) NCARD=1                                        ADNA2140
      IF(NPAR(15).EQ. 2) NCARD=1                                        ADNA2150
      IF(NPAR(15).EQ. 3) NCARD=4                                        ADNA2160
      IF(NPAR(15).EQ. 4) NCARD=4                                        ADNA2170
      IF(NPAR(15).EQ. 5) NCARD=2                                        ADNA2180
      IF(NPAR(15).EQ. 7) NCARD=1                                        ADNA2190
      IF(NPAR(15).EQ. 8) NCARD=1                                        ADNA2200
      IF(NPAR(15).EQ. 9) NCARD=1                                        ADNA2210
      IF(NPAR(15).EQ.10) NCARD=6                                        ADNA2220
      IF(NPAR(15).EQ.11) NCARD=6                                        ADNA2230
      IF(NPAR(15).EQ.13) NCARD=1                                        ADNA2240
      IF(NPAR(15).NE.14)  GO TO 20                                      ADNA2250
      CARDNR=NPAR(17)/8.0                                               ADNA2260
      NCARD=INT(CARDNR)                                                 ADNA2270
      TEST=CARDNR-NCARD                                                 ADNA2280
      IF(TEST.GT.0.1) NCARD=NCARD+1                                     ADNA2290
   20 CONTINJE                                                          ADNA2300
      N12=12                                                            ADNA2310
C *** READ MATERIAL PROPERTIES                                          ADNA2320
      DO 50 J=1,NUMMAT                                                  ADNA2330
          READ(5,9000) DUMMY                                            ADNA2340
 9000 FORMAT(20A4)                                                      ADNA2350
          DO 45 I=1,NCARD                                               ADNA2360
              READ(5,9000) DUMMY                                        ADNA2370
   45             CONTINUE                                              ADNA2380
   50     CONTINUE                                                      ADNA2390
C *** READ STRESS OUTPUT TABLE CARDS                                    ADNA2400
      IF(NPAR(13).EQ.0) GO TO 61                                        ADNA2410
      DO 60 I=1,NSTRES                                                  ADNA2420
          READ(5,9000)DUMMY                                             ADNA2430
   60     CONTINUE                                                      ADNA2440
   61 CONTINUE                                                          ADNA2450
C *** READ AND GENERATE ELEMENT DATA CARDS                              ADNA2460
      IF(NPAR(14).EQ.0) NPAR(14)=1                                      ADNA2470
      NEL=NPAR(14)-1                                                    ADNA2480
  130 READ(5,9002) INEL,IINC                                            ADNA2490
      IF(IINC.EQ.0) IINC=1                                              ADNA2500
 9002 FORMAT(I5,15X,I5)                                                 ADNA2510
      READ(5,9004)(INP(I),I=1,8)                                        ADNA2520
 9004 FORMAT(8I5)                                                       ADNA2530
  140 NEL=NEL+1                                                         ADNA2540
      ML=INEL-NEL                                                       ADNA2550
      IF(ML)150,155,160                                                 ADNA2560
  150 CALL ERROR(8)                                                     ADNA2570
C *** NO GENERATION OF NODE POINTS REQUIRED                             ADNA2580
```

```
155 DO 156 I=1,4                                                      ADNA2590
        I5=I+4                                                        ADNA2600
        I9=I+8                                                        ADNA2610
        NP(I)=INP(I)                                                  ADNA2620
        NP(I5)=0                                                      ADNA2630
        NP(I9)=INP(I5)                                                ADNA2640
156     CONTINUE                                                      ADNA2650
    GO TO 162                                                         ADNA2660
C *** GENERATION OF NODE POINTS REQUIRED                              ADNA2670
160 DO 161 I=1,N12                                                    ADNA2680
        IF(NP(I).EQ.0) GO TO 161                                      ADNA2690
        NP(I)=NP(I)+KN                                                ADNA2700
161     CONTINUE                                                      ADNA2710
162 CONTINUE                                                          ADNA2720
    NUMEL=NUMEL+1                                                     ADNA2730
    WRITE(10) N12,NEL,(NP(I),I=1,N12)                                 ADNA2740
    IF(NEL.EQ.NPAR(2)) RETURN                                         ADNA2750
    IF(NEL.LT.INEL) GO TO 140                                         ADNA2760
    KN=IINC                                                           ADNA2770
    GO TO 130                                                         ADNA2780
    END                                                               ADNA2790
    SUBROUTINE AD3DEE                                                 ADNA2800
C                                                                     ADNA2810
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * ADNA2820
C                                                                     ADNA2830
C *** THIS SUBROUTINE TO READ ADINA 3-D SOLID ELEMENT DATA            ADNA2840
C *** THIS ROUTINE CALLED BY ELTYPE                                   ADNA2850
C                                                                     ADNA2860
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * ADNA2870
C                                                                     ADNA2880
    COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL                          ADNA2890
    DIMENSION NP(20),INP(20)                                          ADNA2900
    NUMMAT=NPAR(16)                                                   ADNA2910
    NSTRES=NPAR(13)                                                   ADNA2920
C *** CALCULATE THE NUMBER OF MATERIAL CASE CARDS                     ADNA2930
    IF(NPAR(15).EQ. 1) NCARD=1                                        ADNA2940
    IF(NPAR(15).EQ. 2) NCARD=2+NPAR(18)                               ADNA2950
    IF(NPAR(15).EQ. 3) NCARD=4                                        ADNA2960
    IF(NPAR(15).EQ. 4) NCARD=4                                        ADNA2970
    IF(NPAR(15).EQ. 5) NCARD=2                                        ADNA2980
    IF(NPAR(15).EQ. 8) NCARD=1                                        ADNA2990
    IF(NPAR(15).EQ. 9) NCARD=1                                        ADNA3000
    IF(NPAR(15).EQ.10) NCARD=6                                        ADNA3010
    IF(NPAR(15).EQ.11) NCARD=6                                        ADNA3020
    IF(NPAR(15).NE.12) GO TO 20                                       ADNA3030
    CARDNR=NPAR(17)/8.0                                               ADNA3040
    NCARD=INT(CARDNR)                                                 ADNA3050
    TEST=CARDNR-NCARD                                                 ADNA3060
```

```
      IF(TEST.GT.0.1) NCARD=NCARD+1                                      ADNA3070
   20 CONTINJE                                                           ADNA3080
      N20=20                                                             ADNA3090
C *** READ MATERIAL PROPERTIES                                           ADNA3100
      DO 50 J=1,NUMMAT                                                   ADNA3110
         READ(5,9000) DUMMY                                              ADNA3120
 9000 FORMAT(20A4)                                                       ADNA3130
         DO 45 I=1,NCARD                                                 ADNA3140
            READ(5,9000) DUMMY                                           ADNA3150
   45       CONTINJE                                                     ADNA3160
   50    CONTINUE                                                        ADNA3170
C *** READ STRESS OUTPUT TABLE CARDS                                     ADNA3180
      IF(NPAR(13).EQ.0) GO TO 61                                         ADNA3190
      DO 60 I=1,NSTRES                                                   ADNA3200
         READ(5,9000) DUMMY                                              ADNA3210
   60    CONTINUE                                                        ADNA3220
   61 CONTINJE                                                           ADNA3230
      IF(NPAR(14).EQ.0) NPAR(14)=1                                       ADNA3240
      NEL=NPAR(14)-1                                                     ADNA3250
  130 READ(5,9002) INEL,IINC                                             ADNA3260
 9002 FORMAT(I5,30X,I5)                                                  ADNA3270
      IF(IINC.EQ.0) IINC=1                                               ADNA3280
      READ(5,9004) (INP(I),I=1,8)                                        ADNA3290
      READ(5,9004) (INP(I),I=9,N20)                                      ADNA3300
 9004 FORMAT(12I5)                                                       ADNA3310
  140 NEL=NEL+1                                                          ADNA3320
      ML=INEL-NEL                                                        ADNA3330
      IF(ML) 150,155,160                                                 ADNA3340
  150 CALL ERROR(9)                                                      ADNA3350
C *** NO GENERATION OF NODE POINTS REQUIRED                              ADNA3360
  155 DO 156 I=1,N20                                                     ADNA3370
         NP(I)=INP(I)                                                    ADNA3380
  156    CONTINUE                                                        ADNA3390
      GO TO 162                                                          ADNA3400
C *** GENERATION OF NODE POINTS REQUIRED                                 ADNA3410
  160 DO 161 I=1,N20                                                     ADNA3420
         IF(NP(I).EQ.0) GO TO 161                                        ADNA3430
         NP(I)=NP(I)+KN                                                  ADNA3440
  161    CONTINUE                                                        ADNA3450
  162 CONTINUE                                                           ADNA3460
      NUMEL=NUMEL+1                                                      ADNA3470
      WRITE(10) N20,NEL,(NP(I),I=1,N20)                                  ADNA3480
      IF(NEL.EQ.NPAR(2)) RETURN                                          ADNA3490
      IF(NEL.LT.INEL) GO TO 140                                          ADNA3500
      KN=IINC                                                            ADNA3510
      GO TO 130                                                          ADNA3520
      END                                                                ADNA3530
      SUBROUTINE ADBEAM                                                  ADNA3540
```

```
C                                                                       
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
C *** THIS SUBROUTINE TO READ ADINA 2NODE BEAM ELEMENTS
C *** THIS ROUTINE CALLED BY ELTYPE
C
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *
C
      COMMON/GCONT/NUMNP,NPAR(20),NELTYP,NUMEL
      N2=2
      NUMMAT=NPAR(15)
      IF(NUMMAT.EQ.0) NUMMAT=1
C *** READ MATERIAL PROPERTIES
      DO 50 J=1,NUMMAT
          DO 45 I=1,2
              READ(5,9000) DUMMY
 9000 FORMAT(20A4)
   45         CONTINUE
   50     CONTINUE
C *** READ STRESS OUTPUT TABLE CARDS
      IF(NPAR(13).EQ.0) GO TO 81
      IF(NPAR(14).EQ.0) NPAR(14)=16
      NST=NPAR(13)
      CARDST=NPAR(14)/16.0
      NCDST=INT(CARDST)
      TEST=CARDST-NCDST
      IF(TEST.GT.0.01) NCDST=NCDST+1
      NST=NST*NCDST
      DO 80 I=1,NST
          READ(5,9000) DUMMY
   80     CONTINUE
   81 CONTINUE
C *** READ OR GENERATE ELEMENT DATA CARDS
      IF(NPAR(17).EQ.0) NPAR(17)=1
      NEL=NPAR(17)-1
  130 READ(5,9002) INEL,II,JJ,IINC
 9002 FORMAT(3I5,15X,I5)
      IF(IINC.EQ.0) IINC=1
  140 NEL=NEL+1
      ML=INEL-NEL
      IF(ML) 150,155,160
  150 CALL ERROR(10)
C *** NO GENERATION OF NODE POINTS REQUIRED
  155 I=II
      J=JJ
      GO TO 162
C *** GENERATION OF NODE POINTS REQUIRED
  160 I=I+KN
```

```
      J=J+KN                                                            ADNA4030
  162 CONTINUE                                                          ADNA4040
      NUMEL=NUMEL+1                                                     ADNA4050
      WRITE(10) N2,NEL,I,J                                              ADNA4060
      IF(NEL.EQ.NPAR(2)) RETURN                                         ADNA4070
      IF(NEL.LT.INEL) GO TO 140                                         ADNA4080
      KN=IINC                                                           ADNA4090
      GO TO 130                                                         ADNA4100
      END                                                               ADNA4110
```

```
C ******* SUBROUTINES NFRAME AND CCRT2 DELETED **********                APR1981
      SUBROUTINE GEOM2(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                   AUXL0080
C                                                                       APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *APR1981
C                                                                       APR1981
C********* USER SUP>LIED SUBROUTINE SPACE ************                  APR1981
C                                                                       APR1981
CC *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *APR1981
      CALL ERROR(14)                                                    AUXL0090
      RETURN                                                            AUXL0100
      END                                                               AUXL0110
      SUBROUTINE NSTRUS                                                 AUXL0120
C                                                                       AUXL0130
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * AUXL0140
C                                                                       AUXL0150
C *** THIS SUBROUTINE TO READ NON SAP TRUSS ELEMENTS                    AUXL0160
C *** CALLED BY ELTYPE                                                  AUXL0170
C                                                                       AUXL0180
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * AUXL0190
C                                                                       AUXL0200
      RETURN                                                            AUXL0210
      END                                                               AUXL0220
      SUBROUTINE NSPLAN                                                 AUXL0230
C                                                                       AUXL0240
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * AUXL0250
C                                                                       AUXL0260
C *** THIS SUBROUTINE TO READ NON SAP 2 D 8 NODE PLANE ELEMENTS         AUXL0270
C *** CALLED BY ELTYPE                                                  AUXL0280
C                                                                       AUXL0290
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * AUXL0300
C                                                                       AUXL0310
      RETURN                                                            AUXL0320
      END                                                               AUXL0330
      SUBROUTINE NS3DEE                                                 AUXL0340
C                                                                       AUXL0350
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * AUXL0360
C                                                                       AUXL0370
C *** THIS SUBROUTINE TO READ NON SAP 3-D ELEMENT DATA                  AUXL0380
C *** CALLED BY ELTYPE                                                  AUXL0390
C                                                                       AUXL0400
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * AUXL0410
C                                                                       AUXL0420
      RETURN                                                            AUXL0430
      END                                                               AUXL0440
      SUBROUTINE DATA1(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)                   AUXL0450
C                                                                       AUXL0460
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *APR1981
C                                                                       APR1981
```

```
C ******* USER SUPPLIED DISPLACEMENT DATA SUBROUTINE CALLED BY PSAP1****APR1981
C                                                                      AUXL0480
C  *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *APR1981
      RETURN                                                           AUXL0490
      END                                                              AUXL0500
      SUBROUTINE DATA5(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT)
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
C***SUBROUTINE TO READ EACH NODE'S DISPLACEMENT FROM DEVICE 58
C *** CALLED BY PSAP1
C
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
C
      REAL*8 D(6)
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,
     2PSCALE,KDISP,DMAG,KODE
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP
      COMMON/VALUES/ NVALUS
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)
      REWIND 58
      WRITE(6,10)NVALUS
10    FORMAT (///5X,'NUMBER OF DISPLACEMENT SETS TO BE PLOTTED =',I6///)
      DO 20 II=1,NVALUS
      READ(58)NODE,(D(I),I=1,6)
      R1=SNGL(D(1))
      R2=SNGL(D(2))
      R3=SNGL(D(3))
      UPT(II)=R1
      VPT(II)=R2
      WPT(II)=R3
20    CONTINUE
      RETURN
      END
      SUBROUTINE DATA9(NUMPT,XPT,YPT,ZPT,UPT,VPT,WPT,DISPD,NON)       0000362
C                                                                     0000363
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * 0000364
C                                                                     0000365
C *** USER SUPPLIED DISPLACEMENT INPUT SUBROUTINE.                    0000366
C *** CALLED BY PSAP1                                                 0000367
C                                                                     0000368
C *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    * 0000369
C                                                                     0000370
      COMMON/CDATA/NTIME,NTLC                                         0000371
      COMMON/CONTRL/ KGEOM,KDATA,KPLOT,KSYMXY,KSYMXZ,KSYMYZ,NOTAT,XLHT,
     1KHORZ,KVERT,PHI,THETA,PSI,NEWFR,ISCALE,PLOTSZ,XORGN,YORGN,      0000373
     2PSCALE,KDISP,DMAG,KODE                                          0000374
```

```
      COMMON/KOUNT/ NNODE,NNDEST,NUDISP,NVDISP,NWDISP                   0000375
      DIMENSION NUMPT(1),XPT(1),YPT(1),ZPT(1),UPT(1),VPT(1),WPT(1)      0000376
      DIMENSION DISPD(5,3,NON)                                          0000377
C                                                                       0000378
      IF (NUDISP.EQ.0.AND.NVDISP.EQ.0.AND.NWDISP.EQ.0) GO TO 25         0000379
      IF(NTIME.NE.0) GO TO 100                                          0000380
      READ(5,1000) NTLC,SCALEF                                          0000381
 1000 FORMAT(I5,F10.0)                                                  0000382
      IF(SCALEF.EQ.0) SCALEF=1.0                                        0000383
   10 READ(5,2000) N,NLCAS,U,V,W                                        0000384
 2000 FORMAT(2I4,3E12.5)                                                0000385
      DISPD(NLCAS,1,N) = U*SCALEF                                       0000386
      DISPD(NLCAS,2,N) = V*SCALEF                                       0000387
      DISPD(NLCAS,3,N) = W*SCALEF                                       0000388
      IF( (NLCAS.EQ.NTLC).AND.(N.EQ. 1   ) ) GO TO 100                  0000389
      GO TO 10                                                          0000390
  100 NTIME = NTIME + 1                                                 0000391
  200 DO 20 I=1,NNODE                                                   0000392
      UPT(I) = DISPD(NTIME,1,I)                                         0000393
      VPT(I) = DISPD(NTIME,2,I)                                         0000394
      WPT(I) = DISPD(NTIME,3,I)                                         0000395
   20 CONTINUE                                                          0000396
   25 CONTINUE                                                          0000397
      RETURN                                                            0000398
      END                                                               0000399
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                       APR1981
C          THE NEXT SEVEN SUBROUTINES ARE THE ADAPTIVE ROUTINES         APR1981
C          WHICH MODIFY PSAP1 FOR USE WITH THE VERSATEC PLOTTER         APR1981
C                                                                       APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                       APR1981
C                                                                       APR1981
      SUBROUTINE CA_CMP                                                 ADPT0010
C                                                                       APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *APR1981
C                                                                       APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PSAP1                      ADPT0020
C          INITIALIZES PLOTTER                                          APR1981
C          PLOTTER WINDOW SET TO 100" X 21.11"                          APR1981
C                                                                       APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *APR1981
C                                                                       APR1981
      CALL WINDOW(0.0,100.0,0.0,21.11)                                  ADPT0030
      CALL PLOTS(0,0,0)                                                 ADPT0040
      CALL PLOT(0.0,20.0,-3)                                            ADPT0050
      RETURN                                                            ADPT0060
```

```
      END                                                                ADPT0070
      SUBROUTINE CALPLT(X,Y,IPEN)                                        ADPT0080
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PSAP1/PLOTX/GARROW/ERROR    ADPT0090
C        BASIC PLOTTING CALL                                             APR1981
C                                                                        APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *    *APR1981
C                                                                        APR1981
      INTEGER IPEN                                                       ADPT0100
      REAL X,Y                                                           APR1981
      CALL PLOT(Y,-X,IPEN)                                               APR1981
      RETURN                                                             ADPT0150
      END                                                                ADPT0160
      SUBROUTINE NOTATE (X,Y,HT,BCD,TH,N)                                ADPT0170
C                                                                        APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *    *APR1981
C                                                                        APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PSAP1                       ADPT0180
C        FOR LETTERING ON PLOT                                           APR1981
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
      INTEGER N                                                          ADPT0190
      REAL X,Y,HT,TH,THR                                                 APR1981
      DIMENSION BCD(1)                                                   ADPT0210
      THR=TH+270.0                                                       APR1981
      CALL SYMBOL(Y,-X,HT,BCD,THR,N)                                     APR1981
      RETURN                                                             ADPT0260
      END                                                                ADPT0270
      SUBROUTINE CALNUM (X,Y,HT,FPN,PH,DEC)                              ADPT0280
C                                                                        APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *    *APR1981
C                                                                        APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PLOTX                       ADPT0290
C        FOR NUMBERING ON PLOT                                           APR1981
C                                                                        APR1981
C  *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *    *APR1981
C                                                                        APR1981
      INTEGER DEC                                                        ADPT0300
      REAL X,Y,HT,PH,FPN,PHR                                             APR1981
      PHR=PH+270.0                                                       APR1981
      CALL NUMBER(Y,-X,HT,FPN,PHR,DEC)                                   APR1981
      RETURN                                                             ADPT0360
      END                                                                ADPT0370
      SUBROUTINE CALWH(X,Y)                                              ADPT0380
C                                                                        APR1981
```

```
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PLOTX                       ADPT0390
C       TO FIND CURRENT LOCATION OF PLOTTER PEN                          APR1981
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
      REAL X,Y,XR,YR,SCALE                                               APR1981
      CALL WHERE(XR,YR,SCALE)                                            APR1981
      X=-YR                                                              APR1981
      Y=XR                                                               APR1981
      RETURN                                                             ADPT0440
      END                                                                ADPT0450
      SUBROUTINE CALINE(X,Y,N)                                           ADPT0460
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PLOTX                       ADPT0470
C       TO DRAW A LINE THRU MULTIPLE POINTS                              APR1981
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
      INTEGER N,I                                                        ADPT0480
      DIMENSION X(1),Y(1)                                                ADPT0500
      CALL PLOT(Y(1),-X(1),3)                                            APR1981
      DO 100 I=2,N                                                       ADPT0510
         CALL PLOT(Y(I),-X(I),2)                                         APR1981
  100 CONTINUE                                                           ADPT0550
      RETURN                                                             ADPT0560
      END                                                                ADPT0570
      SUBROUTINE PSTOP                                                   ADPT0580
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
C ***** TO ADAPT FOR NPS VERSAPLOT CALLED BY PSAP1/ERROR                 ADPT0590
C       TO CLOSE OUT PLOTTING DATA SETS                                  APR1981
C                                                                        APR1981
C *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *  APR1981
C                                                                        APR1981
      CALL PLOT(0.,0.,999)                                               ADPT0600
      RETURN                                                             ADPT0610
      END                                                                ADPT0620
```

LIST OF REFERENCES

1. Stenstrom, F.E., Photoelastic Study of Elastic and Plastic Stress Fields in the Vicinity of a Notch, Master's Thesis, Naval Postgraduate School, Monterey, California, December 1980.

2. Engle, E.C., An Investigation of Residual Stresses in Simulated Wing Panels of 7075-T6 Aluminum, Master's Thesis, Naval Postgraduate School, Monterey, California, December 1979.

3. Stuart, G.L., An Investigation of Residual Stress Characterization of 7075-T6 Aluminum for Application in Fatigue Analysis, Master's Thesis, Naval Postgraduate School, Monterey, California, December 1978.

4. Massachusetts Institute of Technology Report 82448-1, A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis (ADINA), by K. Bathe, September 1975 (revised May 1976).

5. Crandall, S.H., Engineering Analysis - A Survey of Numerical Procedures, pp. 171-173, McGraw-Hill, 1956.

6. Heise, U., "Combined Application of Finite Element Methods and Richardson Extrapolation to the Torsion Problem," Conference on the Mathematics of Finite Elements and Applications, ed. by J. R. Whiteman, V. 1., pp. 225-237, Academic Press, 1973.

7. Kibler, A.E., A Finite Element Preprocessor for SAPIV and ADINA, Master's Thesis, Naval Postgraduate School, Monterey, California, September 1977.

8. Howland, R.C.J., "Stress in a Strip of Finite Width, Which is Weakened by a Circular Hole," Philosophical Transactions of the Royal Society, Series A, V. 229, pp. 49-86, London, 1930.

9. ANSI/ASTM B557-79, Standard Methods of Tension Testing Wrought and Cast Aluminum and Magnesium Alloy Products, 1979.

10. Micro-Measurements, Transverse Sensitivity Errors TN-137, undated, Vishay Intertechnology, Inc.

11. Rivello, R.M., Theory and Analysis of Flight Structures, pp. 38-40, McGraw-Hill, 1969.

12. Garske, J.C., An Investigation of Methods for Determining Notch Root Stress from Far-Field Strain in Notched Flat Plates, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 1977.

13. National Aeronatics and Space Administration (NASA) Report CR-1649, Finite Element Analysis of Structures in the Plastic Range, by H. Armen, Jr., A. Pifko, and H.S. Levine, February, 1971.

14. Segerlind, L.J., Applied Finite Element Analysis, p. 251, Wiley, 1976.

15. Zienkiewicz, O.C., The Finite Element Method, 3d Ed., McGraw-Hill Ltd, 1977.

16. David W. Taylor Naval Ship Research and Development Center Report, Accuracy Loss in Distorted Isoparametric Finite Elements, by D. A. Hopkins and L.N. Gifford, September 1978.

17. Cook, R.D., Concepts and Applications of Finite Element Analysis, pp. 87-92, Wiley, 1974.

18. Barlow, J., "Optimal Stress Locations in Finite Element Models," International Journal for Numerical Methods in Engineering, V. 10, pp. 243-251, 1976.

19. Hinton, E., and Campbell, J.S., "Local and Global Smoothing of Discontinuous Finite Element Functions Using a Least Squares Method," International Journal for Numerical Methods in Engineering, V. 8, pp. 461-480, 1974.

20. Peterson, R.E., Stress Concentration Factors, pp. 20-36 and 111-150, Wiley, 1974.

21. Frocht, M.M., "Photoelastic Studies in Stress Concentration," Mechanical Engineering, V. 58, August 1936.

22. Frocht, M.M., "Factors of Stress Concentration in Bars with Deep Sharp Grooves and Fillets in Tension," Proceedings of the Society of Experimental-Stress Analysis, V. 8, No. 2, 1951.

23. Naval Research Laboratory Report 7278, Finite Element Analysis of Notched Tensile Specimens in Plane Stress, by C. A. Griffis, 10 September 1971.

24. Clough, R.W., "The Finite Element Method in Structural Mechanics," Stress Analysis ed. by O. Zienkiewicz and G. Holister, pp. 85-119, Wiley, 1965.

25. Frocht, M.M., and Thomson, R.A., "Further Work on Plane Elastoplastic Stress Distributions," Proceedings of the International Symposium on Photoplasticity, Pergamon Press, 1963.

26. Advisory Group for Aerospace Research and Development Report AGARD-MAN-8-70, Manual on Fatigue of Structures, by W. G. Barrois, pp. 206-227, June 1970.

27. Lubahn, J.D., and Felgar, R.P., Plasticity and Creep of Metals, p. 510, Wiley, 1961.

28. Easterling, L.R., Stress Analysis of Ceramic Turbine Blades by Finite Element Method - Part I, Master's Thesis, Naval Postgraduate School, Monterey, California, March 1978.

29. Preisel, J.H., Stress Analysis of Ceramic Gas Turbine Blades by the Finite Element Method - Part II, Master's Thesis, Naval Postgraduate School, Monterey, California, March 1978.

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