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Bethesda, Md. 20084



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A COMPUTER PROGRAM FOR CALCULATION OF THE RESIDUAL
STRESS DISTRIBUTION AND THE EFFECTIVE STRESS-STRAIN
CURVE OF COLD-FORMED STRUCTURAL MEMBERS

by
R.K. Tacey

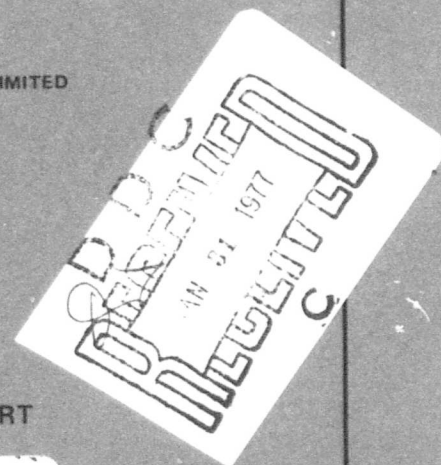
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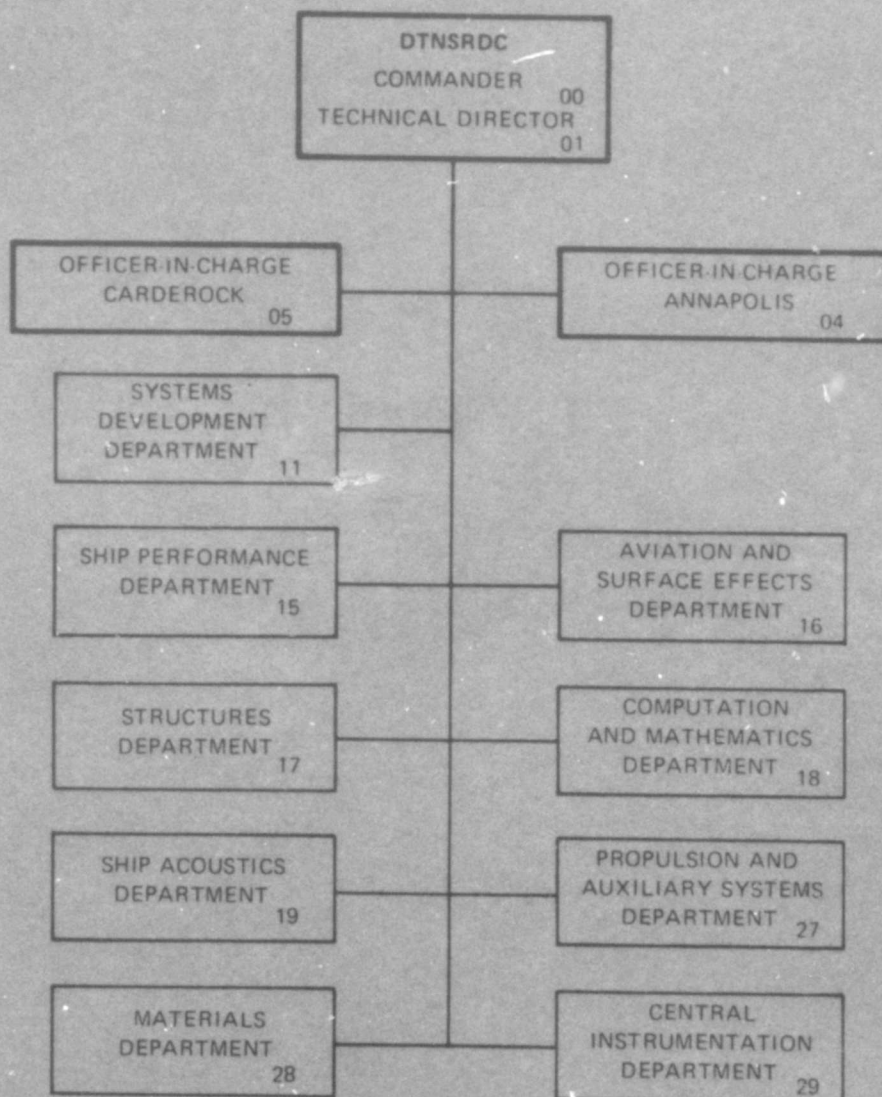
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DTNSRDC Report 76-0141	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER ⑨
4. TITLE (and Subtitle) A COMPUTER PROGRAM FOR CALCULATION OF THE RESIDUAL STRESS DISTRIBUTION AND THE EFFECTIVE STRESS- STRAIN CURVE OF COLD-FORMED STRUCTURAL MEMBERS		5. TYPE OF REPORT & PERIOD COVERED Final rept.
6. AUTHOR(s) Robert K. Tacey		7. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task Area SF 43.422.502 1-1720-555-56
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command Code 035 Washington, D.C. 20362		12. REPORT DATE November 1976
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Sea Systems Command Code 035 Washington, D.C. 20362		13. NUMBER OF PAGES 77
15. SECURITY CLASS. (of this report) UNCLASSIFIED		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) ⑭ DTNSRDC-76-0141		
18. SUPPLEMENTARY NOTES ⑮ F43422		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Cold formed structural members Residual stress distribution Bauschinger effect Strain hardening Effective Stress-strain curves		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) → This report describes a computer program which can be used to calculate the cross sectional residual stress distribution and the effective compressive stress-strain relationship of a cold formed structural member. The program → Copy available to PSC 117 permit fully legible reproduction (Continued on reverse side)		

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is user oriented and requires input of only basic geometry and base metal stress-strain data. The program is general as to the shape of the cross section that may be analyzed. It accounts for inelastic material behavior during initial bending and during springback. Strain hardening and unequal compressive and tensile material stress-strain relationships are included in the analysis. Material properties are homogeneous and isotropic within the individual elements. However, they may vary from element to element. The Bauschinger Effect can be accounted for by utilizing non-dimensional experimental data or theoretical formulations. These different methods may be inserted in the program in modular fashion. The program can analyze the forming process as an operation consisting of up to ten individual bends. Graphs are presented that show close agreement between the program predictions and limited experimental results.

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ABSTRACT

This report describes a computer program which can be used to calculate the cross sectional residual stress distribution and the effective compressive stress-strain relationship of a cold formed structural member. The program is user oriented and requires input of only basic geometry and base metal stress-strain data. The program is general as to the shape of the cross section that may be analyzed. It accounts for inelastic material behavior during initial bending and during springback. Strain hardening and unequal compressive and tensile material stress-strain relationships are included in the analysis. Material properties are homogeneous and isotropic within the individual elements. However, they may vary from element to element. The Bauschinger Effect can be accounted for by utilizing non-dimensional experimental data or theoretical formulations. These different methods may be inserted in the program in modular fashion. The program can analyze the forming process as an operation consisting of up to ten individual bends. Graphs are presented that show close agreement between the program predictions and limited experimental results.

ADMINISTRATIVE INFORMATION

Work on this program was initially funded under in-house Independent Research Program, Task Area FR 0230301. Work was completed under Task Area SF 43.422.502 and Work Unit 1-1720-555.

PROGRAM ASSUMPTIONS

1. The behavior of a structural member may be described completely, on a macroscopic scale, by means of its stress to strain relationship.
2. Each longitudinal fiber of the structural member is subjected to uniaxial strain during the cold rolling process.
3. The structural member is initially straight, but may have initial residual stresses in the direction of its longitudinal axis.
4. The material is homogeneous and isotropic within an element. Stress-strain properties may vary from element to element.

5. Plane cross sections remain plane after deformation.
6. The cross section is symmetric about a plane through the center of curvature and the center of gravity of cross section of the member.
7. The material may have different tensile and compressive engineering stress-strain curves. However, the portions of the curves about their respective proportional limits are about the same shape. Young's modulus is the same for both the tensile and compressive base metal curves.
8. Stress increases monotonically with strain.
9. The Bauschinger Effect may be represented for a given family of materials by one set of nondimensionalized experimental data.
10. Material unloading is linear elastic until the zero stress state is reached. If reverse loading occurs material behavior becomes nonlinear.
11. Shear deformation which occurs in the rolling process is not considered.

PROGRAM FEATURES

1. Analysis of many different cross sectional shapes is possible.
2. Material behavior is characterized by its actual engineering stress-strain curve.
3. Different compressive and tensile stress-strain relationships are allowed. Different base metal stress-strain curves may be input for each element. This allows for different base plates used in the cross section and for weld material that may be present.
4. Inelastic material behavior is taken in account on the initial bend and on subsequent springback.
5. The section neutral axis shifts during bending and during springback.

6. Residual stresses in the longitudinal direction of the straight member before bending may be included.
7. Hardening rules may be easily modified.
8. Multibend operation analysis is available.
9. Automatic output includes the stress and strain history of the cold formed member of all bends as well as the effective stress-strain curve of the member.
10. Optional output includes printout of all stress-strain curves of all elements and important iterative quantities. Additionally, the effective stress-strain curves for a segmented tee section may be obtained.

INTRODUCTION

An understanding of the true load carrying ability of structural members is necessary to produce adequate designs involving those members. This strength is characterized by a load-deflection or stress-strain curve. It is obvious that these curves are needed when the design is inelastic in nature. However, the manufacturing history of the member may make use of stress-strain curves necessary even when the member is designed to function in the elastic region. For instance, residual stresses may be introduced during the manufacture of the member or during the fabrication of the structure. These stresses can act as preloads which may cause inelastic behavior near the design loads of the structure. Additionally, the material characteristics of the member may be altered by forming processes or welding. In particular the cold rolling process may reduce the proportional limit and elastic modulus significantly.

The cold rolling process of forming a curved structural member involves bending a straight structural member to a radius smaller than its design radius. The member springs back to the desired radius upon release of external forces. This process changes some important structural properties of the material, and gives rise to a complex state of residual

stress. A graphical representation of the stress components of this process is shown in Figure 1. A typical theoretical residual stress distribution for a cold rolled plate is given in Figure 2a; one for a typical cold formed tee section, in Figure 2b. As can be seen from Figure 2, the residual stress distributions of the cold rolled plate and the cold formed tee section are in equilibrium when the complete cross section is considered. However, local areas, such as the flange of a tee section, may exhibit unbalanced stresses.

The determination of an effective stress-strain relationship depends on the calculation of residual stress distribution in the cross section of structural element. In the past this calculation could be performed only after simplifying assumptions had been made. One assumption has been that the material behaves in an elastic-perfectly plastic manner as shown in Figure 3. A related assumption is the absence of the Bauschinger Effect. This phenomena is an apparent loss in the proportional limit stress in one direction of loading after the material has been loaded plastically in the opposite direction. The assumption elastic-perfectly plastic material behavior ignores an apparent strengthening, known as strain hardening, which may occur at high strains in materials which can develop increased stress with increasing strain in the plastic region. This assumption also incorrectly places the proportional limit at the 0.2 percent offset yield point. The exclusion of the Bauschinger Effect from an analysis of cold forming strength decreases the accuracy of the analysis for many important structural materials. Figure 4 shows the Bauschinger Effect on a uniaxial compression specimen of high strength steel with tensile prestrain. The reduction in the compressive proportional limit is obvious.

DISCUSSION

The need for a method to accurately predict the effect of stress-strain curve of a cold rolled structural component was discussed in the Introduction. Theoretical prediction for cold rolled plates is available, but

does not include the Bauschinger Effect. Predictions for cold formed sections other than plates are done by hand once the residual stress distribution has been obtained.¹ All of these methods involve the use of simplifying assumptions that affect their accuracy. The program presented here is an attempt to describe, on a macroscopic scale, the response of the structural material to the cold rolling process. Care has been taken to keep assumptions as few and as realistic as possible. These assumptions were listed previously.

The program analyzes the component cross section as a system of rectangular elements. The structural properties of each element are maintained in an array and updated during each phase of the rolling process. This approach is necessary in that the material properties are dependent on the strain history of the element. After the rolling process is completed, a series of incremental strains is applied to each element and its stress response calculated. These stresses are then integrated over the cross section to produce the response of the member as a whole. Since the analysis is performed with a system of elements, the restrictions on the type or shape of cross section are few. Any section may be analyzed which is symmetric about a plane through the center of curvature and the center of gravity of any cross section of the member. Additionally, a perpendicular to this plane may not pass through more than one segment of the member, see Figure 5. Element geometry is automatically generated for three often used cross section geometries. These are shown in Figure 6.

Because the material is described by base metal stress to strain relationships, a section made of practically any homogenous, isotropic material may be analyzed. Different stress-strain curves are used for each element. Because of this, sections made of different materials may be analyzed. The effect of welding on the cross section may be accounted for if the curves for the weld material are known. The curves must always be monotonically increasing. This is a mathematical

¹McVee, J., "Residual Stresses in Cold Bent Circular Ring/Frame Segments of Tee Cross Section," NCRE Report N194, Mar 1971. A complete listing of references is given on page 72.

restriction and does not affect results of a plateau type material. A sufficient number of points must be included to adequately describe the shape of the stress-strain curve. Points should be concentrated in the most curvilinear section of the curve. Up to fifty points are allowed for the base metal compressive curves. Young's modulus is calculated from these curves. The tensile base metal curves are calculated from the compressive as a means of facilitating data input. A percentage reduction factor is read and used to calculate stresses for the tensile curves. Strains for the tensile curves are computed by the following equation.

$$\epsilon_{\text{tensile}} = |\epsilon_{\text{comp}}| - |\sigma_{\text{comp}}| * R_F / E$$

where R_F is the input reduction factor and E is the Young's modulus of the curve.

The program accounts for inelastic material behavior on the initial bend and on springback. The neutral axis is shifted on the initial bend and on springback. Any longitudinal residual stresses that are present when the member is straight may be included in the analysis. Additionally, in multibend analysis, residual stress and inelastic effects from each bend are accounted for, and are cumulative.

The Bauschinger Effect is considered both in springback and in final compression phase which determines the material effective stress-strain curve. The user has the option of using hardening rules based on experimental tests or on theoretical considerations. Experimental hardening rules presently included in the program are based on nondimensional uniaxial tests results of high strength steel. Data for curvilinear stress-strain material was generated at DTNSRDC. Data for plateau material specimens was taken from the literature.² In those tests

²O'Brien, C.M., "An Investigation to Show the Magnitude and Significance of the Bauschinger Effect in Submarine Hull Plating," Masters Thesis at the Massachusetts Institute of Technology, May 1963.

various specimens prestrained a certain amount in tension or compression. Then loading is reversed and the load-deflection curves recorded. The various prestrained stress-strain curves are obtained and are nondimensionalized by dividing the stress at a given strain by the base metal stress at the same strain. Figure 7 demonstrates the effect of different amounts of prestrain. To nondimensionalize the data, the procedure described below is followed.

Firstly, an arbitrary strain is selected and the corresponding stress on each curve is determined. These stresses are then divided by the corresponding stress from the base metal curve. These ratios and the selected strains constitute nondimensionalized stress-strain curves from which experimental hardening rules are derived.

This process enables the use of one set of nondimensional data for many materials that obey the same hardening rules but that have different stress to strain relationships. The experimental data feature has the advantage of defining hardening rules for materials that may not follow theoretical rules. If the program is used to analyze a member made of material other than high strength steel, the user should determine if the rules defining the Bauschinger Effect are suitable to that material. Different rules, both theoretical and experimental, may be added by simply writing an appropriate subroutine.

The theoretical hardening rule is a combination of the isotropic and kinematic³ rule and is set up as follows. The maximum difference between the curve suffering the Bauschinger Effect and the base metal curve is calculated. According to the kinematic hardening rule, this difference always occurs at the proportional limit and acts to reduce the proportional limit. It is multiplied by a factor whose default value is 1.0. According to the isotropic hardening rule, the Bauschinger Effect acts to increase the ultimate limit stress. This increase is defined as the maximum difference calculated at the proportional limit multiplied by a factor whose default value is zero. All points on the curve between the proportional limit and the ultimate limit are adjusted by an amount

³Mendelson, A., "Plasticity: Theory and Application," MacMillan Company, 1968.

calculated by linear interpolation. Thus the curve suffers the maximum loss of strength near the proportional limit and may actually increase in strength at the ultimate limit. The calculations are made according to the following equations.

$$\Delta \epsilon_{\max} = (\sigma_I - \sigma_{PLI})/E$$

$$\Delta \epsilon = \Delta \epsilon_{\max} (\epsilon_{IA} - \epsilon_{PLA})/(\epsilon_{uA} - \epsilon_{PLA}) * F_{uL}$$

$$- \Delta \epsilon_{\max} (\epsilon_{uA} - \epsilon_{IA})/(\epsilon_{uA} - \epsilon_{PLA}) * F_{PL}$$

$$\Delta \sigma = \Delta \epsilon * E$$

where

$\Delta \epsilon_{\max}$	is the maximum strain difference
σ_I	is the stress that occurred in the initial direction of loading
σ_{PLI}	is the proportional limit stress in the initial direction of loading
E	is the Young's modulus
$\Delta \epsilon$	is the strain difference between the base metal curve and the affected curve
ϵ_{uA}	is the ultimate limit strain in the reversed direction of loading
ϵ_{PLA}	is the proportional limit strain in the reversed direction of loading
ϵ_{IA}	is the applied strain on the base metal curve in the reversed direction of loading
$\Delta \sigma$	is the stress difference between the base metal curve in the reversed direction of loading and the affected curve
F_{PL}	is the proportional limit reduction factor which is user supplied
F_{uL}	is the ultimate limit increase factor which is user supplied

Figure 8 shows the effect of the two curve fitting parameters on the shape of the predicted stress-strain curve of structural member made of high strength steel with a plateau type base metal stress-strain curve. These parameters are input by the user and may vary with a change in geometry of the section or a change in material.

Output includes the residual stress pattern due to the cold forming process and an effective stress-strain curve that incorporates the effects of residual and the Bauschinger Effect with strain hardening. Also, a set of curves is available for a segmented tee cross section. Here the web is divided into three equal area segments and an effective stress-strain curve produced for each. A fourth curve is produced that represents the effective flange strength.

PROGRAM PROCEDURE

DEFINITIONS (All "Y" distances and radii are measured to the innermost fiber of the structural member)

A(I)	element cross sectional area
C	change in curvature due to bending
C _{SB}	change in curvature due to springback
R	fully bent radius
E	Young's modulus
RF	final radius after springback
Y(I)	distance to centroid of element "I"
Y _O	neutral axis after bending prior to springback
Y _{SB}	neutral axis after springback
$\sigma(I)$	residual stress in element "I"
$\sigma_B(I)$	stress due to bending
$\epsilon(I)$	strain due to C
$\epsilon_{SB}(I)$	strain due to C _{SB}

For any given bend in a multibend analysis or for a single-bend analysis the procedure of the program is as follows.

Define change in curvature due to current bend after selecting an arbitrary value for Y_o and R

$$C = 1.0/(R + Y_o) - 1.0/(R_p + Y_{SBP})$$

where R_p and Y_{SBP} are the radius and neutral axis location of the previous bend. On the first bend R_p is infinite for an initially straight member and thus the second term goes to zero. Next elemental strains due to the change in curvature are defined.

$$\epsilon(I) = C * (Y(I) - Y_o) + \sigma_1(I)/E$$

Stresses are now developed for each element by applying the strain to the appropriate element stress-strain curve. Each element has two stress-strain curves associated with it. One is compressive; the other, tensile. Once the stresses are obtained, forces are calculated and equilibrium checked. If the sum of forces in the cross section is not small compared to the average of the absolute values of the tensile and compressive forces then a new Y_o is selected and the above procedure repeated. The applied moment necessary to bend to the chosen radius is computed by summation of elemental moments. The strain in each element due to bending of the structural member is now known for the current value of the fully bent radius. This strain may be thought of as pre-strain. Modified stress-strain curves are generated for each element. If the strains are elastic no change is made in the element curves. Otherwise the curves are changed according to the hardening rule used.

The next step is chose an arbitrary value for Y_{SB} , the spring-back neutral axis. The change in curvature due to springback, C_{SB} , is then defined,

$$C_{SB} = 1.0/(R + Y_o) - 1.0/(R_f + Y_{SB})$$

Elastic springback strains are computed next

$$\epsilon_{SB}(I) = C_{SB} * (Y_{SB} - Y(I))$$

Stresses are then obtained from stress-strain curves previously modified for the Bauschinger Effect and strain hardening. These stresses are due to springback only. The total strain after springback is then calculated as follows. See Figure 9.

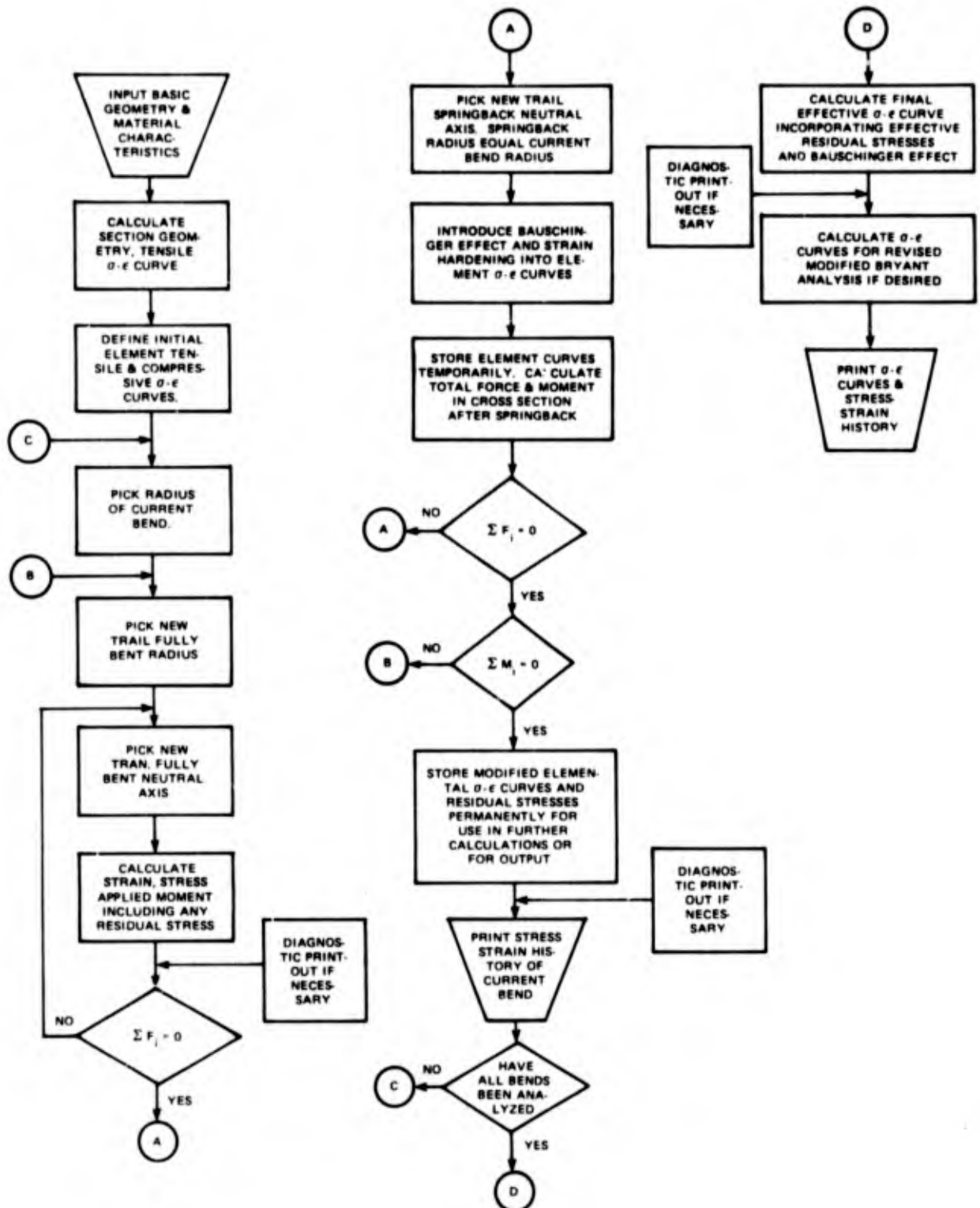
$$\epsilon_T = \epsilon_{SB} - \sigma_B(I)/E$$

This strain is then used to calculate the final residual stress distribution due to bending plus springback. Forces and moments are then calculated and equilibrium conditions checked. If force equilibrium conditions are satisfied then the Y_{SB} assumed is correct. If not, a new Y_{SB} is chosen and the springback computations repeated. Moment equilibrium is checked once Y_{SB} is correct. If moment equilibrium is satisfied the next bend is analyzed using the residual stress distribution and modified element stress-strain curves and initial conditions. If the last bend has been analyzed, the effective stress-strain curve for the cross section is developed.

The effective stress-strain is developed from the final residual stress distribution and the modified element stress-strain curves. A strain is applied to each element and its stress response is calculated. This stress is then weighed by the ratio of the area of the element to that of the total section. These weighted stresses are then integrated over the cross section to give an effective stress that corresponds to the applied strain. A flow chart of the program logic follows.

EXPERIMENTAL WORK

Experimental data needed to evaluate predictions of the program is extremely limited as far as the effect of the cold forming process on the effective stress-strain curve of a structural component is concerned. Such data presented in this report consists of effective stress-strain curves of tee sections made of high strength steel.



One stiffener is made of material that has a plateau stress-strain curve while that of the other is curvilinear. Additionally, data is available on the residual stress distribution in a cold formed tee as shown in Figure 10. The tee was made of high strength steel with a curvilinear stress-strain curve. Experimental data was obtained by hole drilling and slicing techniques. This data provides a check on the calculated residual stress distribution. Accuracy in this calculation is necessary for accuracy in the subsequent calculation of an effective stress-strain curve. The agreement is very good, especially in the web area which constitutes the upper eighty percent of the figure. Agreement in the flange area is also good. However, difficulties arise in obtaining experimental measurements of stresses in the flange and flange-web intersection. High stress gradients hinder the hole drilling and slicing methods to a large extent. Slicing is also hampered by geometry of the of the cross section near the web-flange intersection.

The experimental effective stress-strain curves were obtained from uniaxial specimens of tee cross section shown in Figure 11. These specimens were cut from straightened segments of external tee ring stiffeners. When a curved external tee section is straightened a strain distribution results which is similar to that of a cold formed internal tee stiffener. This also removes the possibility of local buckling of the web during straightening. The original external ring stiffener was machined from base metal plate. This produces a stress free ring without heat treatment which may affect material properties.

It should be noted that on bending of structural members an elastic core is developed. This is the area of the cross section which remains elastic and in which the neutral axis of the member is located. For the particular geometries presented the elastic core is calculated to be totally in the flange. Other cross sections may develop the elastic core outside the flange and such cases should be investigated.

Figure 12 shows the experimental effective stress-strain curve and the base metal compression plateau stress-strain curve of the tee

section. The reduction in proportional limit is approximately fifty five percent. Also shown is a predicted curve using the kinematic-isotropic hardening rule. The coefficient of ultimate limit increase and the coefficient of proportional limit reduction are equal to 2.0. These numbers were obtained by a trial and error process. To use this hardening rule effectively, one must be able to determine the coefficients more easily. Figure 13 is essentially the same plot as Figure 12 except the predicted effective stress-strain curve has been calculated using experimental hardening rules. Agreement is within five percent. The predicted curve is lower than the experimental one. This may be the result of the nondimensional data used for the plateau hardening rule. This data exhibits a severe reduction in strength at high strain rates. The comparison of theoretical and experimental results for a high strength steel with a curvilinear stress-strain curve does not exhibit the five percent discrepancy of the plateau type material.

Figure 14 shows the base metal stress-strain curve and the experimental effective stress-strain curve of the second tee section. This work was conducted by Bond at DTNSRDC. Observe the base metal curve above the proportional limit is curvilinear rather than plateau in nature. The reduction in the proportional limit stress is approximately sixty percent. Also shown is the predicted effective stress-strain curve using experimental hardening rules. Agreement is within two percent. The kinematic isotropic hardening rule is not shown because it depends on trial and error determination of two necessary constants.

FUTURE WORK

The program documented herein gives the designer an inexpensive and easily used tool not available in the past. However, the program in its present state is limited in the scope of its validation and

experimental hardening data. The limitations are both on the number of data available to the program and in fact that the data available represent only one loading cycle. Data should be collected to provide more detailed information on material response in the range of 0.1 percent to 2.0 percent prestrain. This data should represent a loading history that is cyclic in nature.

The experimental data used to assess the program's accuracy is limited to one residual stress distribution and two effective stress-strain curves. More data of this nature should be generated for different cross sections and materials.

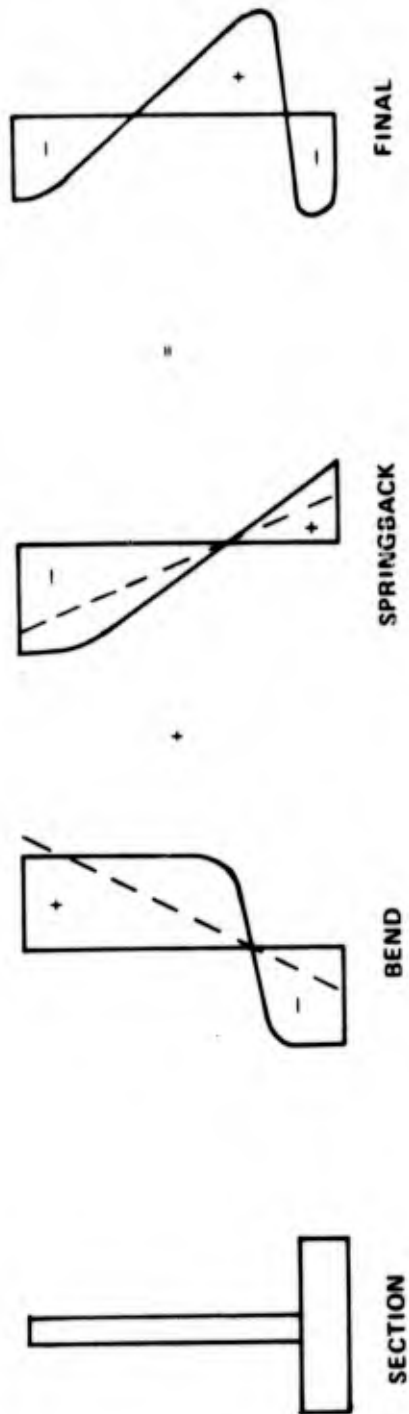
There is some experimental indication^{*} that, due to the mechanics of the rolling process, the state of strain in a flanged structural member, does not follow the assumption of planes before deformation remaining plane after deformation. This is not unexpected but should be investigated. Also, the effect of shear deformation normally present in the rolling process should be investigated.

ACKNOWLEDGMENTS

Mr. D.T. McDevitt made many helpful suggestions during the design and testing of the cold formed tee specimens and during the writing of this report.

Mr. C.D. Bond provided technical guidance during coding of the program as did Mr. T.E. Reynolds.

^{*} Cordinanao, H.V., "Structural Properties of Cold Formed Tee Shapes," DTNSRDC Materials Department Research and Development Report MAT-74-25 August 1974.



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Figure 1 - Stress Patterns due to Cold Rolling of a Tee Section

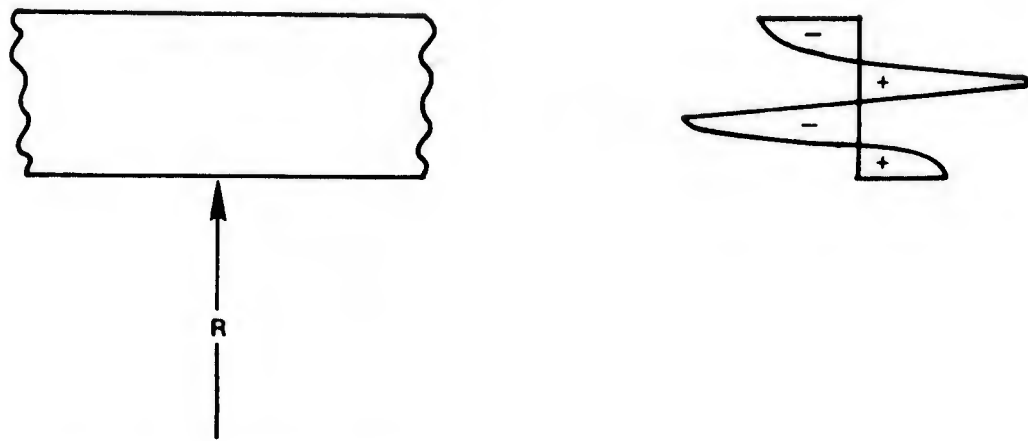


Figure 2a - Typical Residual Stress Pattern for a Cold Rolled Plate

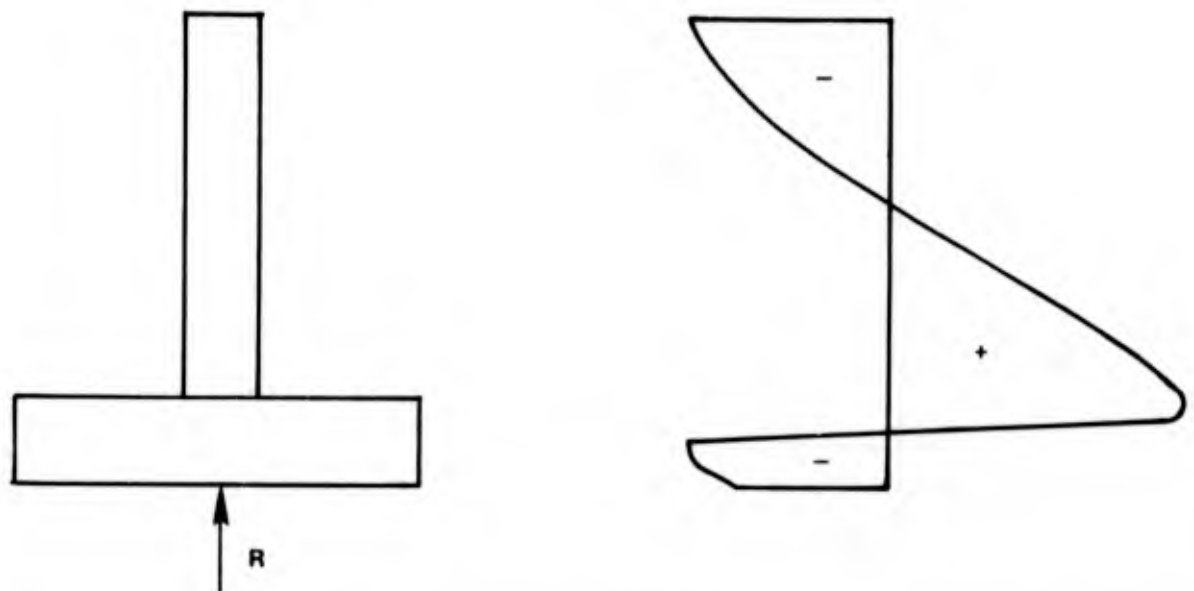


Figure 2b - Typical Residual Stress Pattern for a Cold Formed Tee Section

Figure 2 - Typical Residual Stress Patterns

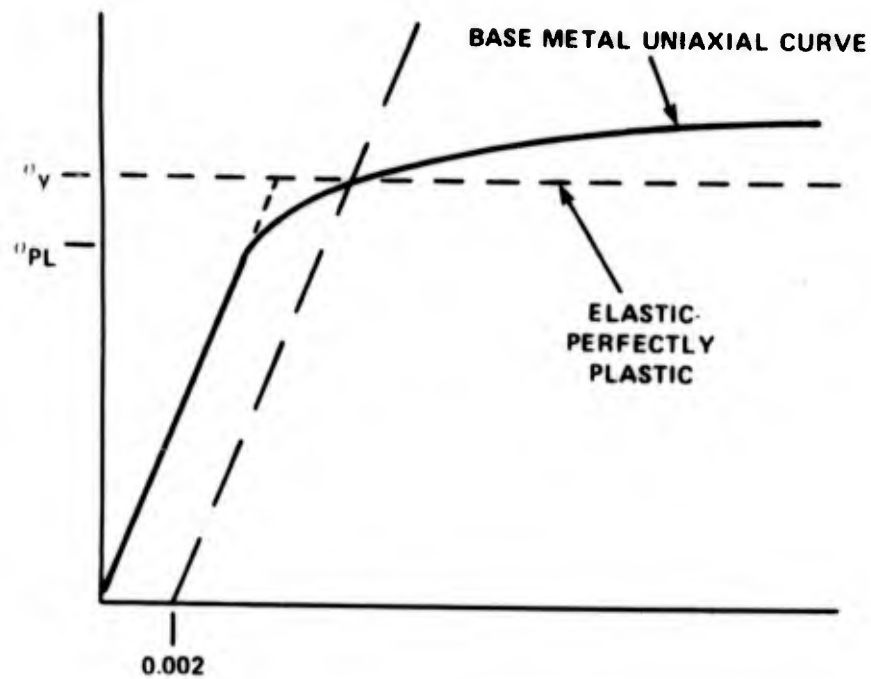


Figure 3 - Stress-Strain Curve of an Elastic-Perfectly Plastic Material

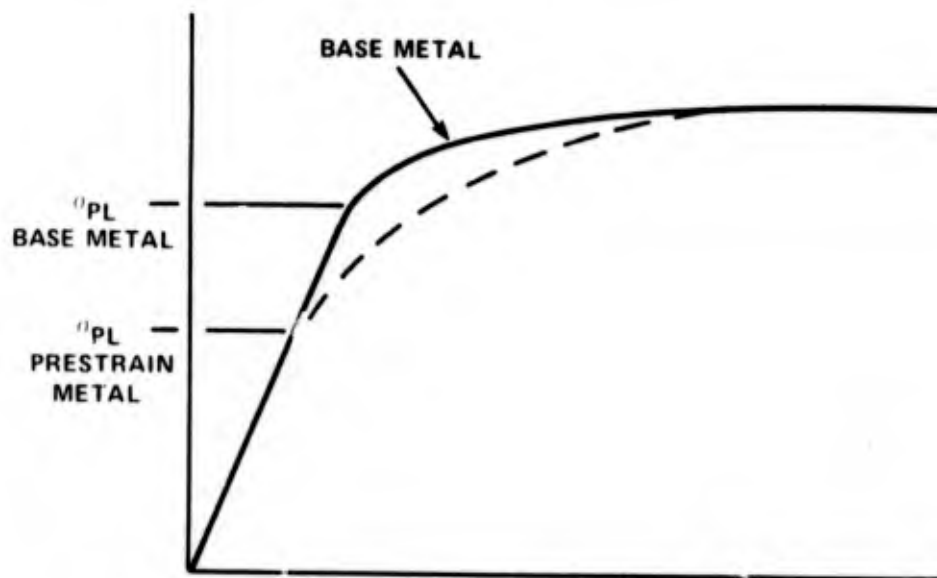
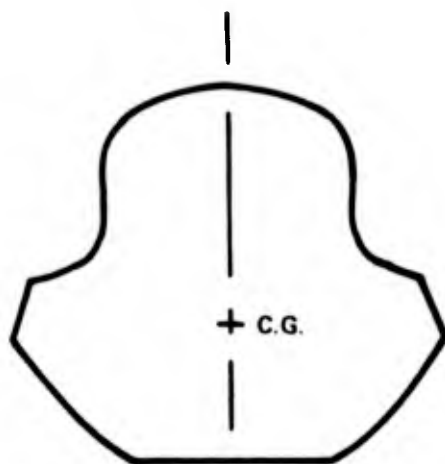
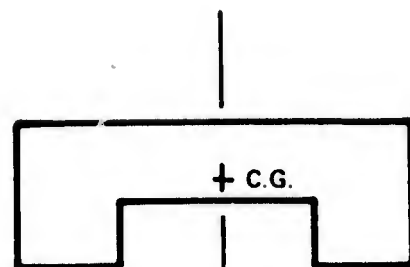


Figure 4 - Bauschinger Effect in a Uniaxial Specimen of High Strength Steel

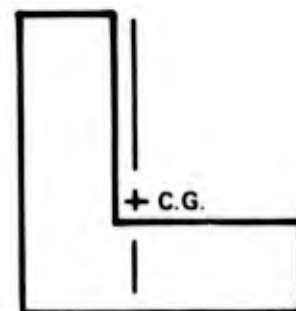


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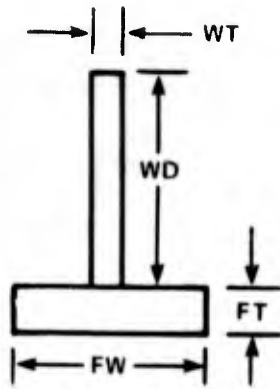
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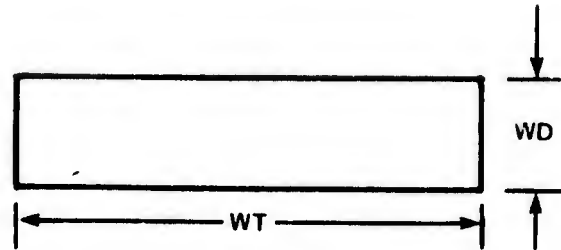
+ CENTER OF
 CURVATURE

NOT ALLOWABLE

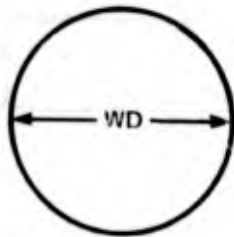
Figure 5 - Restrictions on Cross Sections that may be Analyzed



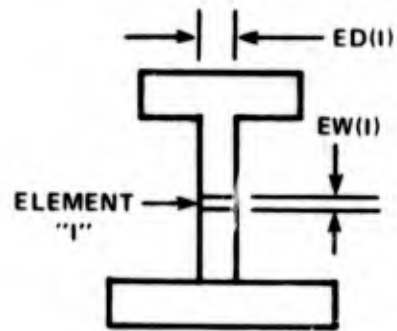
IGEOM = 0



IGEOM = 1



IGEOM = 2



IGEOM = 3

Figure 6 - Cross Section Geometry Options

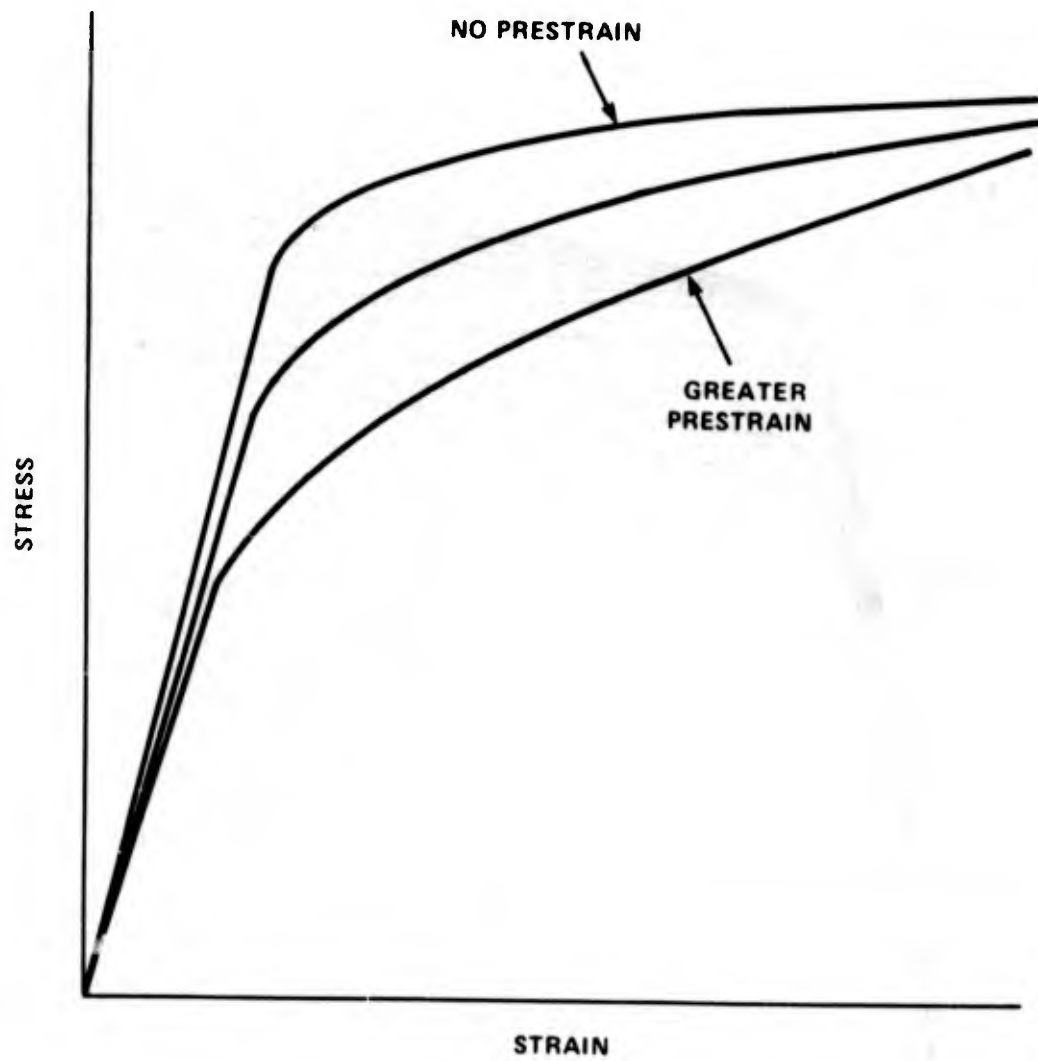


Figure 7 - Representation of the Effect of Prestrain on the Effective Stress-Strain Curve

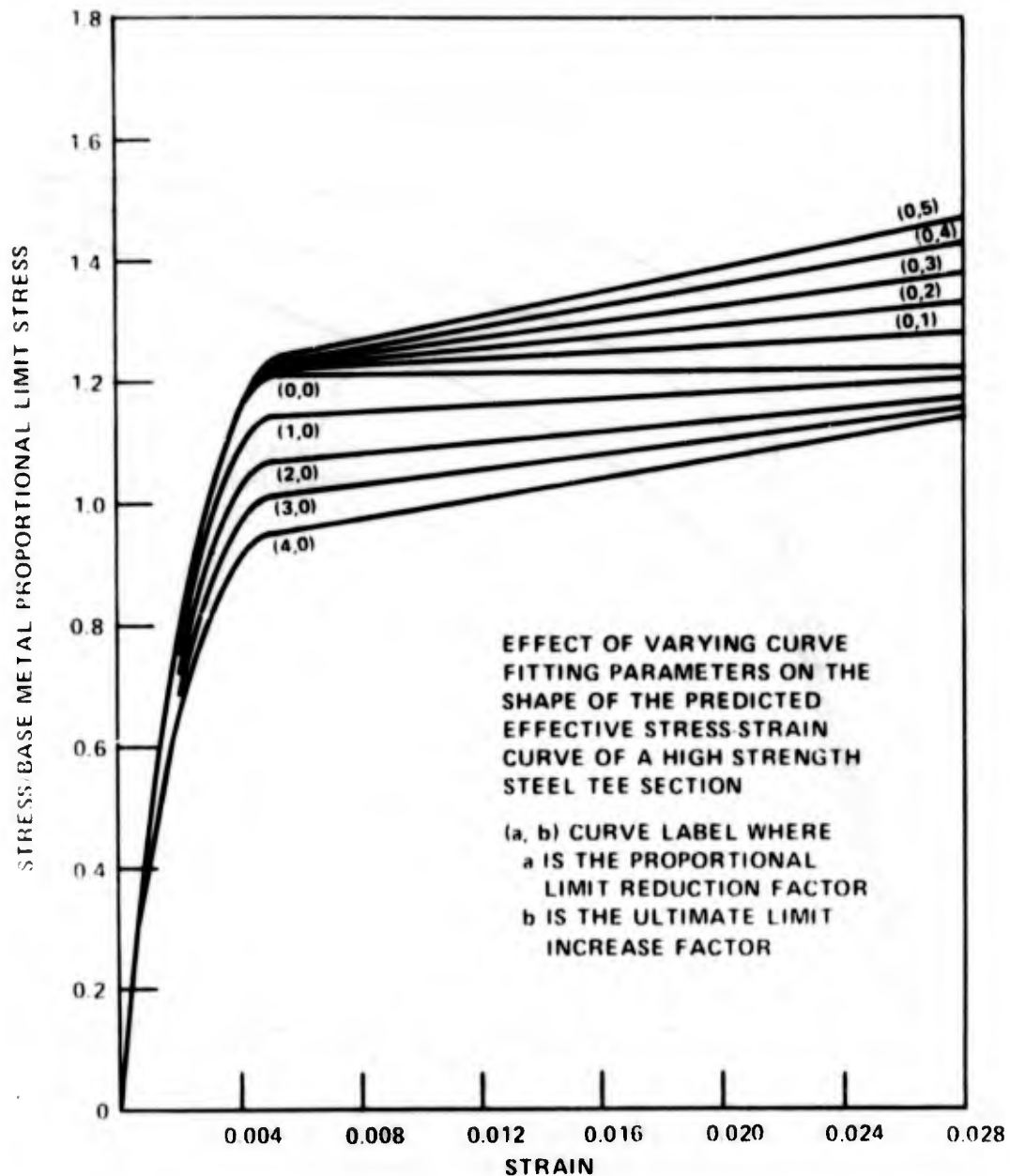


Figure 8 - Effect of Varying Curve Fitting Parameters on the Shape of a Predicted Effective Stress-Strain Curve

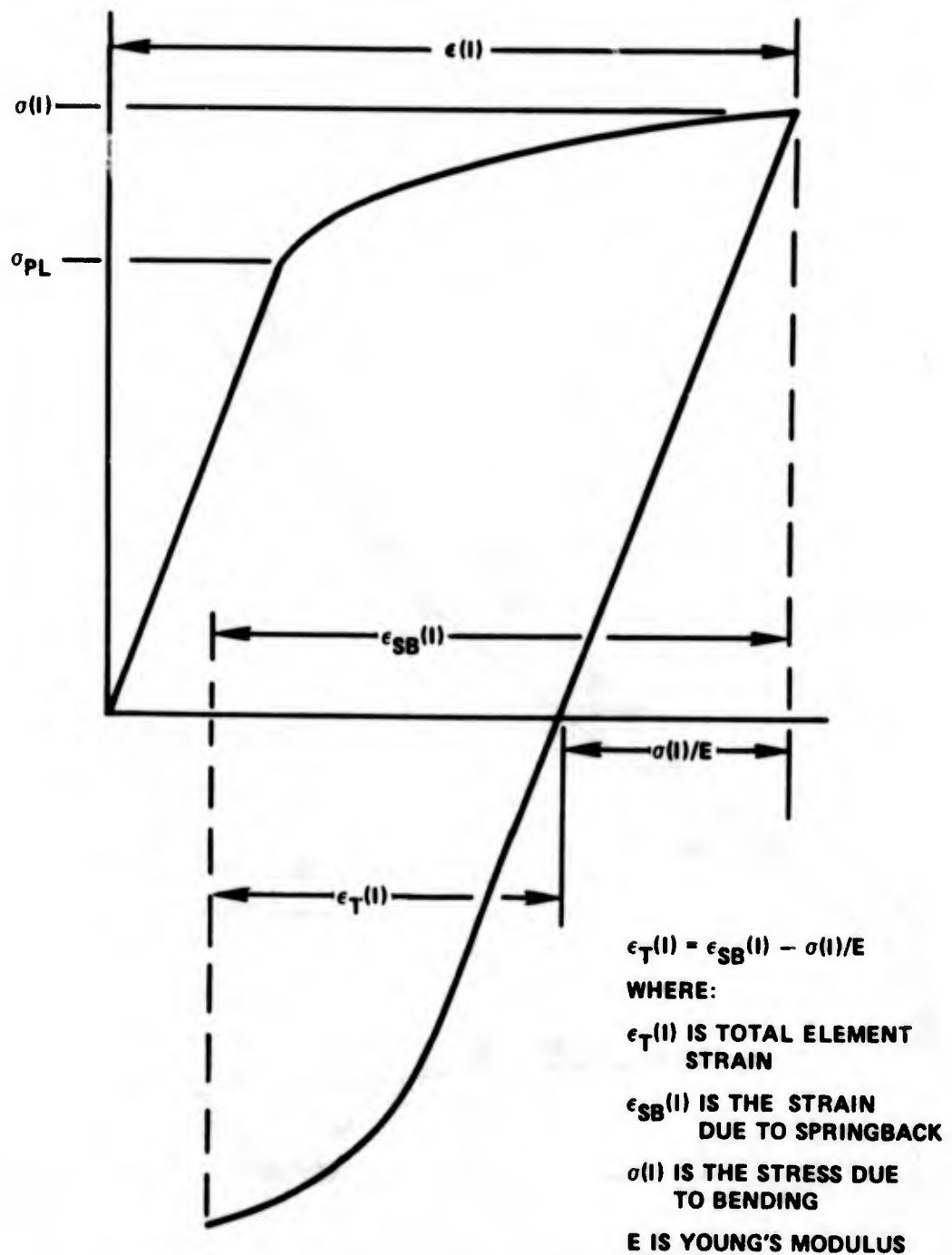


Figure 9 - Element Strain due to Bending and Springback

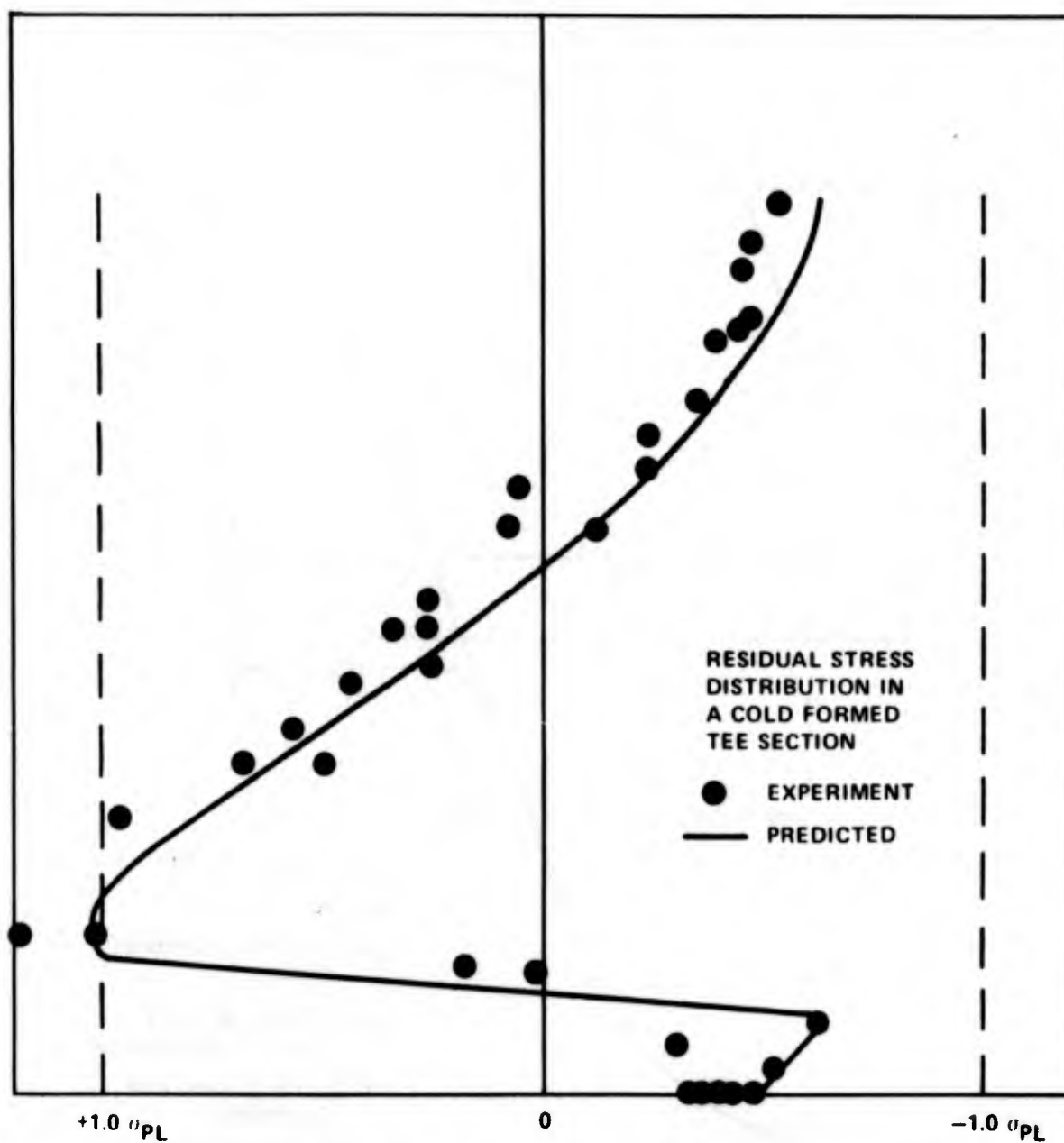
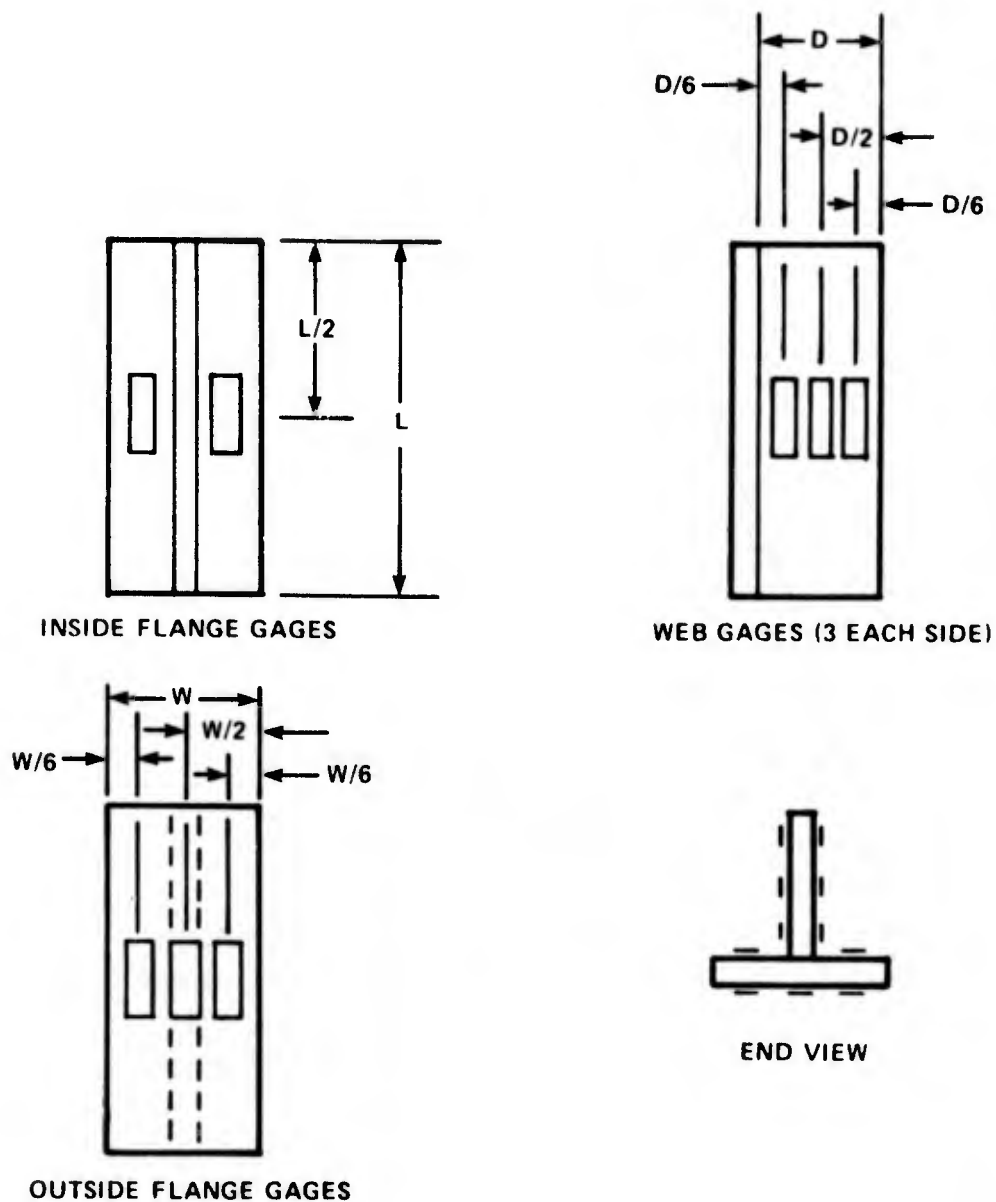


Figure 10 - Residual Stress Distribution in a Cold-Formed Tee Section



NOT TO SCALE

Figure 11 - Strain Gage Locations on Uniaxial Cold-Formed Tee Section Specimens

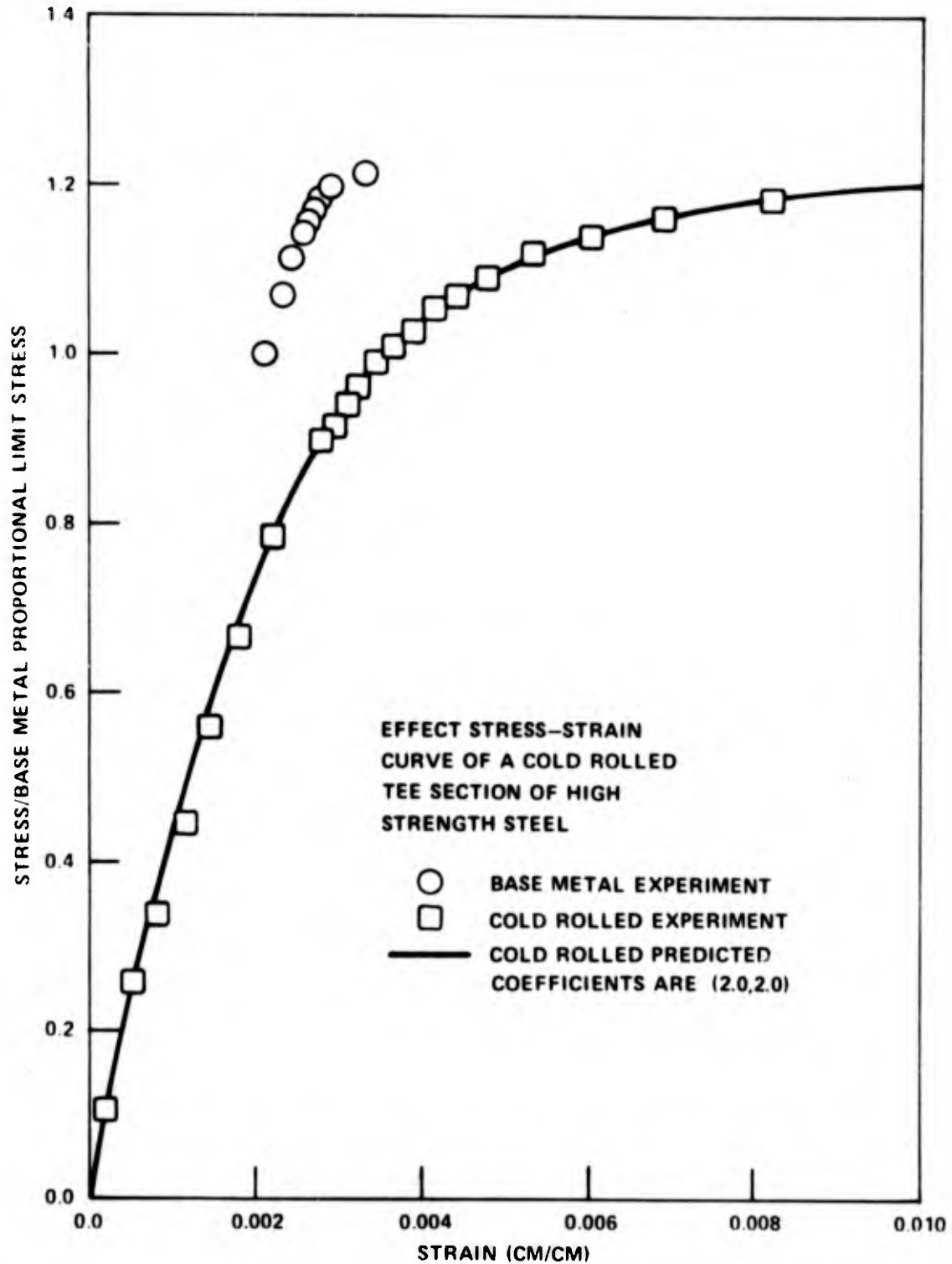


Figure 12 - Effective Stress-Strain Curve of a Cold Rolled Tee Section of Material that has a Plateau Stress-Strain Curve using the Kinematic-Isotropic Hardening Rule

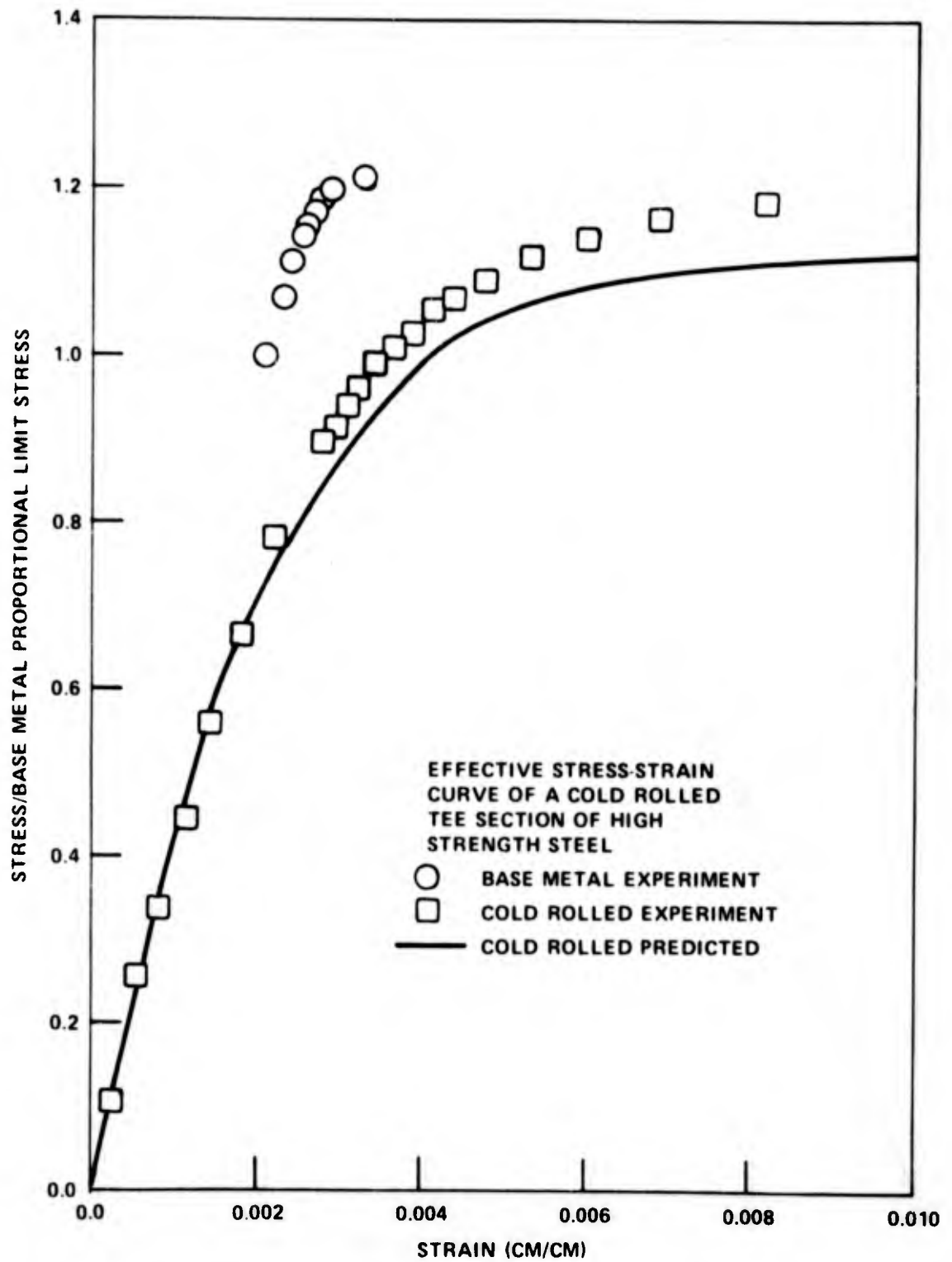


Figure 13 - Effective Stress-Strain Curve of a Cold Rolled Tee Section of Material that has a Plateau Stress-Strain Curve using Experimental Hardening Rule

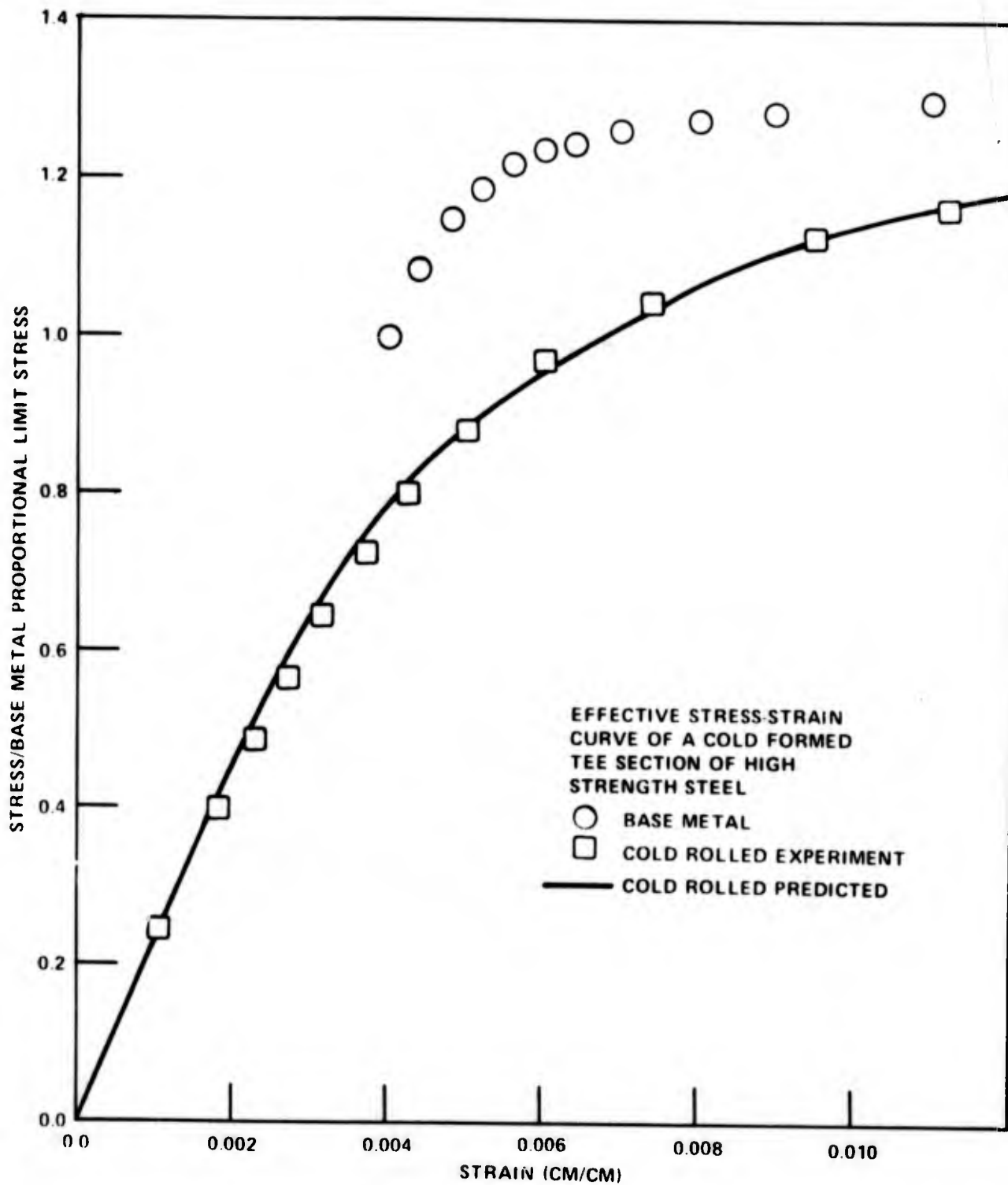


Figure 14 - Effective Stress-Strain Curve of a Cold Formed Tee Section of Material that has a Curvilinear Stress-Strain Curve using Experimental Hardening Rule

APPENDIX A

INPUT DESCRIPTION, SAMPLE PROBLEM AND OUTPUT

Input to the program consists of basic geometry, certain indices and base metal compressive stress-strain curves. The following text gives a complete description of data formats and options. All variables are listed in the order in which they should appear, and the format or field in which they appear is given. If the parameter is an integer value and has to be right justified, the letter "R" will appear in the format or field specification.

CARD SET (NUMBER OF CARDS)

PARAMETER (FIELD) AND DESCRIPTION

A
(1)

TITLE (8A10) Title of problem.

B
(1)

IBENDS (1-5R) Number of bends used in the analysis. Up to ten bends are allowed.

NE (6-10R) Number of elements. A maximum of 50 is allowed. This number should be evenly divisible by four for "tee" sections.

ICRV (11-15R) Number of base metal stress-strain curves to be read in. A maximum of "NE" curves are allowed.

KBE (16-20R) Equal to 11 - Use kinematic - isotropic hardening rule; Equal to 21 - Use experimental hardening rule for high strength steel with a curvilinear base metal stress - strain curve; Equal to 22 - Use experimental hardening rule for high strength steel with a plateau base metal stress-strain curve.

IGEOM (21-25R) Equal to 0 for tee section; Equal to 1 for a rectangular section; Equal to 2 for a circular section; Equal to 3 for a section of arbitrary shape.

	INEX (26-30R) Equal to or less than zero for an internal tee stiffener; Greater than zero for an external stiffener.
	MODSQD (31-35R) Equal to 0 - Stress-strain curves for a segmented tee section are not printed; Not equal to 0 - Curves will be printed.
	ITSTR (36-40R) Equal to 0 - No initial stress is to be read; Not equal to 0 - read initial stresses later in input.
	DEBUGR (41-45R) Equal to 0 - No print-out of intermediate stress-strain curves; Less than 0 - Print out all intermediate curves; Greater than 0 but less than or equal to "NE" - Print out intermediate curves for the element whose index is equal to DEBUGR.
	ITR (46-50R) Equal to 0 - No printout of iterative quantities; Not equal to zero - Print out iterative quantities.
C (1 or 2)	RADI1 (I), I = 1, IBENDS (1-80@10) Radii of consecutive bends. The last radius given must be the design radius. All radii are measured to the innermost fiber.
D (1)	WD (1-10) Web depth, shell to flange
IGEOM = 0	WT (11-20) Web thickness
	FW (21-30) Flange width
	FT (31-40) Flange thickness
IGEOM = 1	WD (1-10) Section dimension in radial direction
	WT (11-20) Section dimension perpendicular to radial direction

IGEOM = 2

IGEOM = 3

E

(1)

WD (1-10) Section diameter

Skip this card

SRED (1-10) Percentage reduction to be applied to compressive stress-strain curves to obtain tensile curves.

STRNK (11-20) Strain increment to be used in the calculation of the effective stress-strain curve. The total strain range of this curve will be $49 \times \text{STRNK}$.

FABSTR (21-30) Fabrication stress to be applied to calculated effective stress-strain curves.

SPLF (31-40) Factor to multiply the calculated kinematic reduction in the proportional limit of each element $\text{KBE} = 11$. Default value is 1.0. Both SPLF and SUF must be zero for default values to be supplied.

SUF (41-50) Factor to multiply the calculated isotropic increase in the ultimate limit of each element if $\text{KBE} = 11$. Default value is 0.0.

F

(ICRV/20)

NPAT(I), I = 1, ICRV (1-80@5R) Number of Points in each of the base metal stress-strain curves to be read in later.

G

(NE/40)

NPA(I), I = 1, NE (1-80@2R) Index of stress-strain curve to be used for element "I." The first curve read in has an index of 1. The last curve read has an index of ICRV. Elements are numbered in ascending order from the innermost fiber. Thus NPA (1)

H
(NPAT(I)
Cards for
the "I" curve)

specifies the stress-strain curve of the innermost element. NPA(NE) specifies the stress-strain curve of the outermost element. For tee sections one fourth of the total number of elements are located in the flange while the remaining elements are placed in the web.

STRESS(J), STRAIN(J), J = 1, NPAT (I) (1-10, 11-20) The stress and strain values associated with point "J." The first point must be (0.0, 0.0). The second point must be the proportional limit stress and strain. The last point is taken to be the ultimate limit. There is one card per point. All stress-strain curves are read consecutively.

I
(NE/8)

SIL(I), I = 1, NE (8F10.3) Values of initial stress. Read only if ITSTR is not equal to zero.

J
(NE)

ED(I), EW(I), I = 1, NE (1-10, 11-20)
ED(I) is the depth of element "I."
EW(I) is the width of element "I."
Use only if IGEOM = 3.

SAMPLE PROBLEM

The problem that follows is included to give the user an idea of the output format and of those parameters printed with the standard output. More detailed output is available, but is usually obtained only for debugging purposes. This extra output consists of the stress-strain history of one or all elements and of intermediate values of certain iterative quantities.

The listing of the example problem data is followed by the output produced when that data was analyzed.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
EXAMPLE OF MULTIBEND ANALYSIS																																							
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
			4					2	0				2						1	1																			
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2	0	.	0								1	7	.	5							1	6	.	0							1	5	.	0					
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	.	4	0								0	.	3	0							1	.	5	0							0	.	5	0					
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

0	.	0	3								0	.	0	0	0	5					0	.	0									2	.	5						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
2	.	0																																						
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				6					7																														
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8	1	0	0	0	.	0				0	.	0	2	0	0																								
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

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EXAMPLE OF MULTIBEND ANALYSIS

FRAME IS INTERNAL

KINEMATIC-ISOTROPIC HARDENING USED

DESIGN RADIUS	15.000
WEB DEPTH	1.400
WEB THICKNESS	.300
FLANGE WIDTH	1.500
FLANGE THICKNESS	.500
NUMBER OF ELEMENTS	20
TENSILE STRENGTH REDUCTION	.030
STRAIN INCREMENT	.000500
PROPORTIONAL LIMIT REDUCTION FACTOR	2.500
ULTIMATE LIMIT INCREASE FACTOR	2.000
FRAME AREA	1.170
CENTROID	.591
RADII OF CONSECUTIVE BENDS	20.000 17.500 16.000 15.000

MATERIAL COMPRESSIVE INPUT STRESS-STRAIN CURVE 1
 PROPORTIONAL LIMIT STRESS 87100. 0.2 PERCENT YIELD STRESS 87147.

STRESS	STRAIN	ES	ET
0.	0.000000	0.	.300345E+08
87100.	.002900	.300345E+08	.244719E+08
87120.	.003560	.244719E+08	.240602E+05
87132.	.004230	.205986E+08	.210843E+05
87190.	.006880	.126730E+08	.213705E+05
87500.	.021450	.407925E+07	.212766E+05

MATERIAL TENSILE COMPUTED STRESS-STRAIN CURVE 1
 PROPORTIONAL LIMIT STRESS 84487. 0.2 PERCENT YIELD STRESS 84532.

STRESS	STRAIN	ES	ET
0.	0.000000	0.	.300345E+08
84487.	.002813	.300345E+08	.243325E+08
84506.	.003473	.243325E+08	.233389E+05
84518.	.004143	.204004E+08	.204522E+05
84574.	.006793	.124504E+08	.207298E+05
84875.	.021363	.397306E+07	.206387E+05

MATERIAL COMPRESSIVE INPUT STRESS-STRAIN CURVE 2
 PROPORTIONAL LIMIT STRESS 77000. 0.2 PERCENT YIELD STRESS 79990.

STRESS	STRAIN	ES	ET
0.	0.000000	0.	.299611E+08
77000.	.002570	.299611E+08	.288809E+08
78000.	.002700	.288809E+08	.606061E+07
79000.	.002900	.272414E+08	.375000E+07
79500.	.003100	.256452E+08	.580235E+06
80000.	.004600	.173913E+08	.887574E+05
81000.	.020000	.405000E+07	.649351E+05

MATERIAL TENSILE COMPUTED STRESS-STRAIN CURVE 2
 PROPORTIONAL LIMIT STRESS 74690. 0.2 PERCENT YIELD STRESS 77591.

STRESS	STRAIN	ES	ET
0.	0.000000	0.	.299611E+08
74690.	.002493	.299611E+08	.288570E+08
75660.	.002622	.288570E+08	.591460E+07
76630.	.002821	.271651E+08	.365121E+07
77115.	.003020	.255314E+08	.570925E+06
77600.	.004520	.171685E+08	.861023E+05
78570.	.014919	.394450E+07	.629911E+05

ELEMENT GEOMETRY AND INITIAL STRESS

WIDTH	DEPTH	Y	STRESS
1.5000	.1000	.0503	0.
1.5000	.1000	.1500	0.
1.5000	.1000	.2500	0.
1.5000	.1000	.3500	0.
1.5000	.1000	.4500	0.
.3000	.0933	.5467	0.
.3000	.0933	.6400	0.
.3000	.0933	.7333	0.
.3000	.0933	.8267	0.
.3000	.0933	.9200	0.
.3000	.0933	1.0133	0.
.3000	.0933	1.1067	0.
.3000	.0933	1.2000	0.
.3000	.0933	1.2933	0.
.3000	.0933	1.3867	0.
.3000	.0933	1.4800	0.
.3000	.0933	1.5733	0.
.3000	.0933	1.6667	0.
.3000	.0933	1.7600	0.
.3000	.0933	1.8533	0.

RADIUS AFTER SPRINGBACK FOR BEND 1 20.000
 FULLY BENT RADIUS 18.721
 NEUTRAL AXIS AFTER SPRINGBACK .624
 FULLY BENT NEUTRAL AXIS .379
 APPLIED MOMENT .371553E+05

STRESS AND STRAIN HISTORY OF SECTION DUE TO COLD FORMING FOR BEND 1 OF 4 RADIUS IS 20.000

I	Y(I)	BENDING STRAIN	STRESS	SPRINGBACK STRAIN	STRESS	FINAL STRAIN	STRESS
1	.0500	-.0172061	-87410.	.0022229	66763.	-.0006946	-20861.
2	.1500	-.0119704	-87298.	.0018358	55136.	-.0010780	-32376.
3	.2500	-.0067346	-87187.	.0014486	43509.	-.0014614	-43891.
4	.3500	-.0014988	-45015.	.0010615	31882.	-.0004409	-13243.
5	.4500	.0037370	84511.	.0006744	20255.	.0034981	78413.
6	.5467	.0087983	77869.	.0003002	8994.	.0028992	77817.
7	.6400	.0136850	78177.	-.0000611	-1831.	.0025482	76346.
8	.7333	.0185717	78485.	-.0004224	-12656.	.0021971	65829.
9	.8267	.0234585	78491.	-.0007837	-23481.	.0018360	55010.
10	.9200	.0283452	78491.	-.0011450	-34307.	.0014747	44185.
11	1.0133	.0332319	78491.	-.0015063	-45132.	.0011134	33360.
12	1.1067	.0381187	78491.	-.0018677	-55957.	.0007521	22534.
13	1.2000	.0430054	78491.	-.0022290	-66782.	.0003988	11709.
14	1.2933	.0478921	78491.	-.0025903	-69801.	.0000295	884.
15	1.3867	.0527789	78491.	-.0029516	-70709.	-.0003318	-9941.
16	1.4800	.0576656	78491.	-.0033129	-71169.	-.0006931	-20766.
17	1.5733	.0625523	78491.	-.0036742	-71629.	-.0010544	-31992.
18	1.6667	.0674391	78491.	-.0040355	-72089.	-.0014157	-42417.
19	1.7600	.0723258	78491.	-.0043968	-72537.	-.0017770	-53242.
20	1.8533	.0772125	78491.	-.0047581	-72903.	-.0021383	-64067.

EQUILIBRIUM CHECK OF RESIDUAL STRESS DISTRIBUTION

UNBALANCED FORCE IN CROSS SECTION IS -156.
 UNBALANCED MOMENT IN CROSS SECTION IS -107.

RADIUS AFTER SPRINGBACK FOR BEND 2 17.500
 FULLY BENT RADIUS 16.509
 NEUTRAL AXIS AFTER SPRINGBACK .618
 FULLY BENT NEUTRAL AXIS .429
 APPLIED MOMENT .370476E+05

STRESS AND STRAIN HISTORY OF SECTION DUE TO COLD FORMING FOR BEND 2 OF 4 RADIUS IS 17.000

I	Y(I)	HENDING STRAIN	STRESS	SPRINGBACK STRAIN	STRESS	FINAL STRAIN	STRESS
1	.0500	-.0046955	-87357.	.0021848	65620.	-.0007309	-81981.
2	.1500	-.0040236	-87256.	.0018002	54069.	-.0011121	-33400.
3	.2500	-.0033518	-87118.	.0014157	42519.	-.0014920	-44012.
4	.3500	-.0012761	-38328.	.0010311	30969.	-.0002481	-7453.
5	.4500	.0037152	78413.	.0006465	19418.	.0032637	78413.
6	.5467	.0041343	77923.	.0002748	8233.	.0028756	77872.
7	.6400	.0047732	78284.	-.0000842	-2521.	.0025287	75763.
8	.7333	.0054070	78413.	-.0004431	-13275.	.0021741	65138.
9	.8267	.0060308	78413.	-.0008020	-24029.	.0018191	54384.
10	.9200	.0066544	78413.	-.0011610	-34783.	.0014862	43630.
11	1.0133	.0072780	78413.	-.0015199	-45537.	.0010973	32876.
12	1.1067	.0079016	78413.	-.0018788	-56291.	.0007383	22122.
13	1.2000	.0085251	78413.	-.0022377	-67045.	.0003794	11368.
14	1.2933	.0091487	78413.	-.0025967	-69831.	.0000205	614.
15	1.3867	.0097723	78413.	-.0029556	-70714.	-.0003385	-10140.
16	1.4800	.0103959	78413.	-.0033145	-71171.	-.0006974	-20894.
17	1.5733	.0110195	78413.	-.0036735	-71628.	-.0010563	-31648.
18	1.6667	.0116430	78413.	-.0040324	-72085.	-.0014152	-42402.
19	1.7600	.0122666	78413.	-.0043913	-72531.	-.0017742	-53156.
20	1.8533	.0128902	78413.	-.0047503	-72895.	-.0021331	-63918.

EQUILIBRIUM CHECK OF RESIDUAL STRESS DISTRIBUTION

UNBALANCED FORCE IN CROSS SECTION IS 145.
 UNBALANCED MOMENT IN CROSS SECTION IS 29.

RADIUS AFTER SPRINGBACK FOR BEND 3 16.000
 FULLY BENT RADIUS 15.156
 NEUTRAL AXIS AFTER SPRINGBACK .618
 FULLY BENT NEUTRAL AXIS .464
 APPLIED MOMENT .370410E+05

STRESS AND STRAIN HISTORY OF SECTION DUE TO COLD FORMING FOR BEND 3 OF 4 RADIUS IS 16.000

I	Y(I)	BENDING STRAIN	STRESS	SPRINGBACK STRAIN	STRESS	FINAL STRAIN	STRESS
1	.0500	-.0043819	-87330.	.0021849	65622.	-.0007299	-21922.
2	.1500	-.0038804	-87232.	.0018003	54072.	-.0011112	-33375.
3	.2500	-.0033775	-87062.	.0014157	42521.	-.0014901	-44755.
4	.3500	-.0012509	-37569.	.0010311	30970.	-.0002228	-6692.
5	.4500	.0031437	78413.	.0006466	19419.	.0032637	78413.
6	.5467	.0036090	77944.	.0002748	8233.	.0028763	77896.
7	.6400	.0040860	78294.	-.0000842	-2521.	.0025290	75772.
8	.7333	.0045553	78335.	-.0004431	-13276.	.0021714	65059.
9	.8267	.0050203	78413.	-.0008021	-24030.	.0018151	54383.
10	.9200	.0054853	78413.	-.0011610	-34785.	.0014562	43628.
11	1.0133	.0059503	78413.	-.0015199	-45539.	.0010972	32874.
12	1.1067	.0064153	78413.	-.0018789	-56294.	.0007383	22119.
13	1.2000	.0068803	78413.	-.0022378	-67048.	.0003793	11365.
14	1.2933	.0073453	78413.	-.0025968	-69831.	.0000204	610.
15	1.3867	.0078103	78413.	-.0029557	-70715.	-.0003306	-10144.
16	1.4800	.0082753	78413.	-.0033147	-71172.	-.0006975	-20849.
17	1.5733	.0087403	78413.	-.0036736	-71629.	-.0010565	-31653.
18	1.6667	.0092053	78413.	-.0040326	-72086.	-.0014154	-42407.
19	1.7600	.0096703	78413.	-.0043915	-72532.	-.0017744	-53162.
20	1.8533	.0101353	78413.	-.0047505	-72895.	-.0021333	-63916.

EQUILIBRIUM CHECK OF RESIDUAL STRESS DISTRIBUTION

UNBALANCED FORCE IN CROSS SECTION IS 273.
 UNBALANCED MOMENT IN CROSS SECTION IS 69.

RADIUS AFTER SPRINGBACK FOR BEND 4 15.000
 FULLY BENT RADIUS 14.268
 NEUTRAL AXIS AFTER SPRINGBACK .608
 FULLY BENT NEUTRAL AXIS .464
 APPLIED MOMENT .369564E+05

STRESS AND STRAIN HISTORY OF SECTION DUE TO COLD FORMING FOR BEND 4 OF 4 RADIUS IS 15.000

I	Y(I)	HENDING STRAIN	STRESS	SPRINGBACK STRAIN	STRESS	FINAL STRAIN	STRESS
1	.0500	-.0039178	-87293.	.0021308	63997.	-.0007828	-23509.
2	.1500	-.0035283	-87191.	.0017492	52537.	-.0011609	-34867.
3	.2500	-.0031304	-86995.	.0013677	41078.	-.0015359	-46131.
4	.3500	-.0010943	-32988.	.0009861	29618.	-.0001149	-3450.
5	.4500	.0031590	78413.	.0006046	18159.	.0032218	78413.
6	.5467	.0035107	77966.	.0002358	7064.	.0028380	77913.
7	.6400	.0038848	78256.	-.0001203	-3606.	.0024916	74651.
8	.7333	.0042506	78335.	-.0004765	-14275.	.0021381	64059.
9	.8267	.0046137	78413.	-.0008326	-24944.	.0017846	53468.
10	.9200	.0049742	78413.	-.0011887	-35614.	.0014285	42799.
11	1.0133	.0053347	78413.	-.0015448	-46283.	.0010724	32130.
12	1.1067	.0056951	78413.	-.0019009	-56953.	.0007463	21460.
13	1.2000	.0060556	78413.	-.0022570	-67532.	.0003602	10791.
14	1.2933	.0064160	78413.	-.0026131	-69886.	.0000040	121.
15	1.3867	.0067705	78413.	-.0029692	-70732.	-.0003521	-10548.
16	1.4800	.0071370	78413.	-.0033253	-71185.	-.0007082	-21218.
17	1.5733	.0074974	78413.	-.0036814	-71639.	-.0010643	-31887.
18	1.6667	.0078579	78413.	-.0040376	-72092.	-.0014204	-42557.
19	1.7600	.0082184	78413.	-.0043937	-72534.	-.0017765	-53226.
20	1.8533	.0085788	78413.	-.0047498	-72894.	-.0021326	-63895.

EQUILIBRIUM CHECK OF RESIDUAL STRESS DISTRIBUTION

UNBALANCED FORCE IN CROSS SECTION IS -118.
 UNBALANCED MOMENT IN CROSS SECTION IS -68.

EFFECTIVE STRESS-STRAIN CURVE INCLUDING
RESIDUAL STRESS AND BAUSCHINGER EFFECT
WITH 0. FABRICATION STRESS

STRESS	STRAIN	ES	ET
0.	0.000000	0.	.295471E+08
14774.	.000500	.295471E+08	.290566E+08
29057.	.001000	.290566E+08	.275650E+08
42339.	.001500	.282257E+08	.236891E+08
52746.	.002000	.263729E+08	.179604E+08
60299.	.002500	.241196E+08	.133475E+08
66093.	.003000	.220311E+08	.997978E+07
70279.	.003500	.200796E+08	.791140E+07
74005.	.004000	.185012E+08	.694083E+07
77220.	.004500	.171599E+08	.588587E+07
79891.	.005000	.159781E+08	.485917E+07
82079.	.005500	.149234E+08	.426595E+06
88209.	.024500	.360037E+07	.322650E+06

APPENDIX B

PROGRAM LISTING

A listing of the program is included to facilitate any modifications or additions that the user may make. An alphabetical listing of the program and subprograms with a description of their functions is included. A flow chart was previously provided to show the logic of the program.

Programs and their Functions

Program	Function
BE	Modifies element stress-strain curves to account for the Bauschinger Effect. Basis for modification is the combined kinematic-isotropic theoretical hardening rule.
BEX	Modifies element stress-strain curves to account for the Bauschinger Effect. Basis for modification is experimentally derived hardening rules.
BENDS	This is the executive program which performs iterative procedures, input and output.
FAB	Modifies final effective stress-strain curves to account for fit up stress.
FORCRV	Produces for effective stress-strain curves for the cross section analyzed for use in the revised modified Bryant program.
FRMCRV	Produces overall effective stress-strain curve.
GETPL	Finds the proportional limit stress of a stress-strain curve.
GETSTN	Finds a strain that corresponds to a given stress according to a specified stress-strain curve.
HSSCL	Provides experimental hardening rule for high strength steel with a curvilinear type stress strain curve.
HSSPT	Provides experimental hardening rule for high strength steel with a plateau type stress-strain curve.
PNTOUT	Eliminates unnecessary points in a stress-strain curve before printing.
S	Finds a stress that corresponds to a given strain according to a specified stress-strain curve.
STNHRD	Modifies a given stress-strain curve to account for strain hardening.
YPT	Finds the stress corresponding to a given percentage offset strain. Used to find the 0.2 percent offset yield stress.

1	C	PROGRAM BENDS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)	BENDS	2
	C		BENDS	3
	C	A PROGRAM TO COMPUTE THE RESIDUAL STRESS DISTRIBUTION AND	BENDS	4
5	C	EFFECTIVE STRESS-STRAIN CURVE OF A COLD FORMED FRAME OF	BENDS	5
	C	GENERAL CROSS SECTION INCORPORATING INELASTIC INITIAL BEND	BENDS	6
	C	AND SPRINGBACK AND THE BAUSCHINGER EFFECT	BENDS	7
	C		BENDS	8
	C	IBENDS NUMBER OF BENDS IN FORMING PROCESS	BENDS	9
	C	NE TOTAL NUMBER OF ELEMENTS, ABOUT 1/4 WILL BE IN FLANGE	BENDS	10
10	C	NPTS NUMBER OF POINTS ON STRESS-STRAIN CURVE	BENDS	11
	C	KBE HARDENING RULE SELECTOR	BENDS	12
	C	IGEOM =0 TEE =1 RECTANGULAR =2 CIRCULAR =3 ARBITRARY	BENDS	13
	C	INEX BLANK OR NEGATIVE-INTERNAL FRAME, POSITIVE-EXTERNAL	BENDS	14
15	C	MODSQD NOT EQUAL ZERO PRODUCES CURVES FOR MOD-MOD BRYANT	BENDS	15
	C	ITSTR NOT EQUAL ZERO INITIAL STRESSES ARE TO BE READ	BENDS	16
	C	DEBUGR ID OF ELEMENT WHOSE STRESS-STRAIN HISTORY IS DESIRED	BENDS	17
	C	IF NEGATIVE ALL ELEMENT STRESS-STRAIN HISTORIES ARE PRINTED	BENDS	18
	C	ITR NOT EQUAL ZERO PRINTS OUT BASIC ITERATION VALUES	BENDS	19
20	C	RADII ARRAY OF RADII USED IN FORMING PROCESS	BENDS	20
	C	WD WEB TOE TO FLANGE DISTANCE, SECTION DEPTH OR DIAMETER	BENDS	21
	C	WT WEB THICKNESS OR SECTION WIDTH	BENDS	22
	C	FW FLANGE WIDTH	BENDS	23
	C	FT FLANGE THICKNESS	BENDS	24
25	C	SRED PERCENT REDUCTION FOR PRODUCING TENSILE CURVE	BENDS	25
	C	STRNK STRAIN INCREMENT USED FOR EFFECTIVE CURVES	BENDS	26
	C	FABSTR FABRICATION STRESS APPLIED TO MOD-MOD BRYANT CURVES	BENDS	27
	C	SPLF PROPORTIONAL LIMIT REDUCTION FACTOR	BENDS	28
	C	SUF ULTIMATE LIMIT INCREASE FACTOR	BENDS	29
30	C	STRESS(I),STRAIN(I) STRESS-STRAIN CURVE	BENDS	30
	C		BENDS	31
	C	COMMON /AA/ ESRCRV(50,50,2),ESNCRV(50,50,2)	BENDS	32
	C	DIMENSION STRESS(50),STRAIN(50),EW(50),ED(50),Y(50),STR(50)	BENDS	33
	C	DIMENSION TITLE(8),STRT(50),STNT(50),STRBE(50),STNBE(50),ESTN(50)	BENDS	34
35	C	DIMENSION STRM(50),STNM(50),NPAT(50),TR(50,50,2),TN(50,50,2)	BENDS	35
	C	DIMENSION TSTR(50),TS(50),SBS(50)	BENDS	36
	C	DIMENSION SBN(50),NPA(50),SIL(50),RADII(10)	BENDS	37
	C	INTEGER DEBUGR	BENDS	38
	C	1 FORMAT(8F10.3)	BENDS	39
	C	2 FORMAT(16I5)	BENDS	40
40	C	3 FORMAT(2F10.3)	BENDS	41
	C	4 FORMAT(8A10)	BENDS	42
	C	5 FORMAT(*0STRESS-STRAIN CURVE FOR ELEMENT *,I3/* INCLUDING B.E. DUE	BENDS	43
	C	1 TO INITIAL BENDING*//5X,*STRESS*,14X,*STRAIN*//)	BENDS	44
45	C	6 FORMAT(5X,*COMPRESSIVE MOMENT IS *,F10.0,3X,*TENSILE MOMENT IS*,	BENDS	45
	C	1 F10.0)	BENDS	46
	C	7 FORMAT(5X,3(F7.4,4X),F8.0)	BENDS	47
	C	8 FORMAT(*0ELEMENT GEOMETRY AND INITIAL STRESS*//6X,*WIDTH*,6X,*DEPT	BENDS	48
	C	1H*,8X,*Y*,6X,*STRESS*//)	BENDS	49
50	C	9 FORMAT(*0STRESS AND STRAIN HISTORY OF SECTION DUE TO COLD FORMING	BENDS	50
	C	AFOB BEND *,I2,* OF *,I2,5X,* RADIUS IS *,F7.3	BENDS	51
	C	1//3X,*I*,6X,*Y(I)*,13X,*BENDING*,20X,*SPRINGBACK*,20X,*FINAL*/21X,	BENDS	52
	C	23(*STRAIN*,8X,*STRESS*,8X)//)	BENDS	53
	C	10 FORMAT(1X,I3,4X,F7.4,3(4X,F10.7,4X,F10.0))	BENDS	54
55	C	11 FORMAT(*1*,//*,8A10//)	BENDS	55
	C	12 FORMAT(*0CURRENT VALUES OF ITERATIVE QUANTITIES*/5X,*RADIUS = *,F7	BENDS	56
	C	1.3,5X,*INCREMENT = *,F8.4)	BENDS	57
	C	13 FORMAT(5X,*INITIAL BEND N.A. = *,F7.4,3X,*INCREMENT = *,F8.5,3X,*C	BENDS	58

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10MP. FORCE IS *,F10.0,3X,*TENSILE FORCE IS *,F10.0)      BENDS 59
14 FORMAT(*DESIGN RADIUS*,T45,F7.3/*SECTION DEPTH*,T45,F7.3/*SECTI BENDS 60
10N WIDTH*,T45,F7.3/*NUMBER OF ELEMENTS*,T40,I3/*TENSILE STRENGTH BENDS 61
2 REDUCTION*,T45,F7.3/*STRAIN INCREMENT*,T45,F8.6)      BENDS 62
15 FORMAT(*DESIGN RADIUS*,T45,F7.3/*WEB DEPTH*,T45,F7.3/*WEB THICK BENDS 63
1NESS*,T45,F7.3/*FLANGE WIDTH*,T45,F7.3/*FLANGE THICKNESS*,T45, BENDS 64
2F7.3/*NUMBER OF ELEMENTS*,T40,I3/*TENSILE STRENGTH REDUCTION*, BENDS 65
3 T45,F7.3/*STRAIN INCREMENT*,T45,F8.6)                BENDS 66
16 FORMAT(*MATERIAL COMPRESSIVE INPUT STRESS-STRAIN CURVE*,I3/* PROP BENDS 67
1ORTIONAL LIMIT STRESS*,2X,F10.0,5X,* 0.2 PERCENT YIELD STRESS*,2X, BENDS 68
2F10.0//5X,*STRESS*,14X,*STRAIN*,16X,*ES*,18X,*ET*//)  BENDS 69
17 FORMAT(3X,F10.0,10X,F8.6)                             BENDS 70
18 FORMAT(*DESIGN RADIUS*,T45,F7.3/*SECTION DIAMETER*,T45,F7.3/ BENDS 71
1*NUMBER OF ELEMENTS*,T40,I3/*TENSILE STRENGTH REDUCTION*,T45, BENDS 72
2 F7.3/*STRAIN INCREMENT*,T45,F8.6)                   BENDS 73
19 FORMAT(*DESIGN RADIUS*,T45,F7.3/*NUMBER OF ELEMENTS*,T40,I3/*TE BENDS 74
1NSILE STRENGTH REDUCTION*,T45,F7.3/*STRAIN INCREMENT*,T45,F8.6) BENDS 75
20 FORMAT(*FRAME AREA*,T45,F7.3/*CENTROID*,T45,F7.3)    BENDS 76
21 FORMAT(5X,*SPRINGBACK N.A. = *,F7.4,3X,*INCREMENT = *,F8.5,3X,*COM BENDS 77
1P. FORCE IS *,F10.0,3X,*TENSILE FORCE IS *,F10.0)      BENDS 78
22 FORMAT(*EXCESSIVE ITERATIONS*//5X,*NO. RADIAL ITERATIONS *,I3/5X, BENDS 79
1*NO. INITIAL BEND ITERATIONS *,I3/5X,*NO. SPRINGBACK ITERATIONS *, BENDS 80
2I3/5X,*COMP. FORCE IS *,F10.0/5X,*TENSILE FORCE IS *,F10.0) BENDS 81
23 FORMAT(*FRAME IS INTERNAL*)                           BENDS 82
24 FORMAT(*FRAME IS EXTERNAL*)                           BENDS 83
25 FORMAT(*ELEMENT *,I3,* SUFFERS BAUSCHINGER EFFECT ON FINAL COMPRE BENDS 84
1SSION*)                                                BENDS 85
26 FORMAT(*1COMPRESSION PHASE ELEMENT STRESS-STRAIN CURVES LACKING RE BENDS 86
1SIDUAL STRESS EFFECTS *//)                             BENDS 87
27 FORMAT(*1RADIUS AFTER SPRINGBACK FOR BEND*,I2,T45,F7.3/*FULLY BEN BENDS 88
1T RADIUS*,T45,F7.3/*NEUTRAL AXIS AFTER SPRINGBACK*,T45,F7.3/*FUL BENDS 89
2LY BENT NEUTRAL AXIS*,T45,F7.3/*APPLIED MOMENT*,T45,E13.6//) BENDS 90
28 FORMAT(*MATERIAL TENSILE COMPUTED STRESS-STRAIN CURVE*,I3/* PROP BENDS 91
1ORTIONAL LIMIT STRESS*,2X,F10.0,5X,* 0.2 PERCENT YIELD STRESS*,2X, BENDS 92
2F10.0//5X,*STRESS*,14X,*STRAIN*,16X,*ES*,18X,*ET*//)  BENDS 93
29 FORMAT(*EQUILIBRIUM CHECK OF RESIDUAL STRESS DISTRIBUTION* BENDS 94
1/*UNBALANCED FORCE IN CROSS SECTION IS *,F10.0, /* UNBALA BENDS 95
2NCED MOMENT IN CROSS SECTION IS *,F10.0)              BENDS 96
99 FORMAT(40I2)                                           BENDS 97
91 FORMAT(*0PROPORTIONAL LIMIT REDUCTION FACTOR*,T45,F6.3/*ULTIMATE BENDS 98
1LIMIT INCREASE FACTOR*,T45,F6.3)                     BENDS 99
92 FORMAT(*0EXPERIMENTAL DATA USED FOR FORMING EFFECTS (HSSCL)* BENDS 100
93 FORMAT(5(5X,F10.0,2X,F8.6))                           BENDS 101
94 FORMAT(*0KINEMATIC-ISOTROPIC HARDENING USED*)        BENDS 102
95 FORMAT(*0EXPERIMENTAL DATA USED FOR FORMING EFFECTS (HSSPT)* BENDS 103
96 FORMAT(*1ELEMENT STRESS-STRAIN CURVES AFTER THE *,I2,* BEND*//) BENDS 104
97 FORMAT(*0RADII OF CONSECUTIVE BENDS *,(T45,F7.3))    BENDS 105
98 FORMAT(3X,F10.0,10X,F8.6,10X,E13.6,6X,F13.6)        BENDS 106
99 FORMAT(*1TEMPORARY ELEMENT STRESS-STRAIN ARRAYS WHEN EXCESSIVE ITE BENDS 107
1RATIONS OCCURRED *//)                                  BENDS 108
C                                                        BENDS 109
C READ AND ECHO INPUT                                    BENDS 110
110 READ(5,4) (TITLE(I),I=1,8)                          BENDS 111
READ(5,2) IBENDS,NE,ICRV,KBE,IGEOM,INEX,MOOS00,ITSTR,DEBUGR,ITR BENDS 112
READ(5,1) (RADII(I),I=1,IBENDS)                         BENDS 113
IF(IGFOM.NE.3) READ(5,1) WD,MT,FW,FT                   BENDS 114
READ(5,1) SRED,STRNK,FABSTR,SPLF,SUF                   BENDS 115

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115	READ(5,2) (NPAT(I),I=1,ICRV)	BENOS	116
	READ(5,90) (NPA(I),I=1,NE)	BENOS	117
	SRED=1.0-SRED	BENOS	118
	DO 47 I=1,ICRV	BENOS	119
	K=NPAT(I)	BENOS	120
120	47 READ(5,3) (TR(I,J,1),TN(I,J,1),J=1,K)	BENOS	121
	DO 48 I=1,NE	BENOS	122
	L=NPA(I)	BENOS	123
	K=NPAT(L)	BENOS	124
	NPA(I)=K	BENOS	125
125	DO 49 J=1,K	BENOS	126
	ESRCRV(I,J,1)=TR(L,J,1)	BENOS	127
	49 ESNCRV(I,J,1)=TN(L,J,1)	BENOS	128
	E=ESRCRV(I,2,1)/ESNCRV(I,2,1)	BENOS	129
	C	BENOS	130
130	C PRODUCE TENSILE BASE METAL ELEMENT CURVES	BENOS	131
	ESRCRV(I,1,2)=ESNCRV(I,1,2)*0.0	BENOS	132
	DO 39 J=2,K	BENOS	133
	ESRCRV(I,J,2)=ESRCRV(I,J,1)*SRED	BENOS	134
	39 ESNCRV(I,J,2)=ESNCRV(I,J,1)-(ESRCRV(I,J,1)-ESRCRV(I,J,2))/E	BENOS	135
135	48 CONTINUE	BENOS	136
	IF(SPLF.EQ.0.0.AND.SUF.EQ.0.0) SPLF=1.0	BENOS	137
	RF=RADI(I,BENDS)	BENOS	138
	SRED=1.0-SRED	BENOS	139
	DO 30 I=1,NE	BENOS	140
140	30 SIL(I)=0.0	BENOS	141
	IF(ITSTR.NE.0) READ(5,1) (SIL(I),I=1,NE)	BENOS	142
	WRITE(6,11) (TITLE(I),I=1,8)	BENOS	143
	IF(INEX.LE.0) WRITE(6,23)	BENOS	144
	IF(INEX.GT.0) WRITE(6,24)	BENOS	145
145	IF(KBE.EQ.11) WRITE(6,94)	BENOS	146
	IF(KBE.EQ.21) WRITE(6,92)	BENOS	147
	IF(KBE.EQ.22) WRITE(6,95)	BENOS	148
	IF(IGECM.EQ.0) WRITE(6,15) RF,WD,WT,FH,FT,NE,SRED,STRNK	BENOS	149
	IF(IGECM.EQ.1) WRITE(6,14) RF,WD,WT,NE,SRED,STRNK	BENOS	150
150	IF(IGECM.EQ.2) WRITE(6,18) RF,WD,NE,SRED,STRNK	BENOS	151
	IF(IGECM.EQ.3) WRITE(6,19) RF,NE,SRED,STRNK	BENOS	152
	IF(KBE.EQ.11) WRITE(6,91) SPLF,SUF	BENOS	153
	C	BENOS	154
155	C SET BASIC PARAMETERS	BENOS	155
	CF=TF=AN=T=AFRAME=YCG=0.0	BENOS	156
	N=0	BENOS	157
	NFE=NE/4	BENOS	158
	NWE=NE-NFE	BENOS	159
	C	BENOS	160
160	C GET ELEMENT GEOMETRY	BENOS	161
	IGFOM=IGECM+1	BENOS	162
	GO TO (71,72,73,74), IGFOM	BENOS	163
	C	BENOS	164
	C TEE SECTION	BENOS	165
165	71 IF(INEX.GT.0) GO TO 32	BENOS	166
	DO 31 I=1,NE	BENOS	167
	IF(I.GT.NFE) GO TO 33	BENOS	168
	ED(I)=FT/FLOAT(NFE)	BENOS	169
	EW(I)=FW	BENOS	170
170	GO TO 31	BENOS	171
	33 ED(I)=WD/FLOAT(NWE)	BENOS	172

	EW(I)=WT	BENDS	173
	31 CONTINUE	BENDS	174
	GO TO 36	BENDS	175
175	32 DO 34 I=1,NE	BENDS	176
	IF(I.GT.NNE) GO TO 35	BENDS	177
	ED(I)=WD/FLOAT(NNE)	BENDS	178
	EW(I)=WT	BENDS	179
	GO TO 34	BENDS	180
180	35 ED(I)=FT/FLOAT(NFE)	BENDS	181
	EW(I)=FW	BENDS	182
	34 CONTINUE	BENDS	183
	36 DO 37 I=1,NE	BENDS	184
	Y(I)=T+ED(I)/2.0	BENDS	185
185	37 T=T+ED(I)	BENDS	186
	GO TO 75	BENDS	187
	C	BENDS	188
	C	BENDS	189
	PECTANGULAR SECTION	BENDS	190
190	72 DO 76 I=1,NE	BENDS	191
	FD(I)=WC/FLOAT(NE)	BENDS	192
	FW(I)=WT	BENDS	193
	Y(I)=T+ED(I)/2.0	BENDS	194
	76 T=T+ED(I)	BENDS	195
	GO TO 75	BENDS	196
195	C	BENDS	197
	C	BENDS	198
	CIRCULAR SECTION	BENDS	199
	73 DO 77 I=1,NE	BENDS	200
	FD(I)=WC/FLOAT(NF)	BENDS	201
	Y(I)=T+ED(I)/2.0	BENDS	202
	T=T+ED(I)	BENDS	203
200	77 EW(I)=SQRT(WD*WD/4.0-(WD/2.0-Y(I)) ²)*2.0	BENDS	204
	GO TO 75	BENDS	205
	C	BENDS	206
	C	BENDS	207
	ARBITRARY SECTION	BENDS	208
205	74 DO 78 I=1,NE	BENDS	209
	READ(5,3) ED(I),EW(I)	BENDS	210
	Y(I)=T+ED(I)/2.0	BENDS	211
	78 T=T+ED(I)	BENDS	212
	75 DO 46 I=1,NE	BENDS	213
210	AFRAME=AFRAME+ED(I)*EW(I)	BENDS	214
	46 YCG=YCG+ED(I)*EW(I)*Y(I)	BENDS	215
	SD=T	BENDS	216
	YCG=YCG/AFRAME	BENDS	217
	VD=YCG	BENDS	218
215	WRITE(6,20) AFRAME,YCG	BENDS	219
	WRITE(6,97) (RADII(I),I=1,IBENDS)	BENDS	220
	SRED=1.0-SRED	BENDS	221
	DO 53 I=1,ICRV	BENDS	222
	K=NPAT(I)	BENDS	223
220	E=TR(I,2,1)/TN(I,2,1)	BENDS	224
	DO 57 J=1,K	BENDS	225
	STRESS(J)=TR(I,J,1)	BENDS	226
	STRAIN(J)=TN(I,J,1)	BENDS	227
	STRT(J)=TR(I,J,1)*SRED	BENDS	228
225	57 STNT(J)=TN(I,J,1)-(TR(I,J,1)-STRT(J))/E	BENDS	229
	SPLBMC=GETPL(STRESS,STRAIN,K,1)		
	SPLBMT=GFTPL(STRT,STNT,K,1)		
	SVC=VPT(STRESS,STRAIN,K,0.002)		

230	SVT=VPT(STRT,STNT,K,0.002)	BENDS	230
	DO 58 J=2,K	BENDS	231
	TN(1,J,2)=STRESS(J)/STRAIN(J)	BENDS	232
	TN(2,J,2)=STRT(J)/STNT(J)	BENDS	233
	IF(J.EQ.K) GO TO 58	BENDS	234
	TR(1,J,2)=(STRESS(J+1)-STRESS(J-1))/(STRAIN(J+1)-STRAIN(J-1))	BENDS	235
235	TR(2,J,2)=(STRT(J+1)-STRT(J-1))/(STNT(J+1)-STNT(J-1))	BENDS	236
	53 CONTINUE	BENDS	237
	TN(1,1,2)=TN(2,1,2)=0.0	BENDS	238
	TR(1,1,2)=STRESS(2)/STRAIN(2)	BENDS	239
	TR(2,1,2)=STRT(2)/STNT(2)	BENDS	240
240	TR(1,K,2)=(STRESS(K)-STRESS(K-1))/(STRAIN(K)-STRAIN(K-1))	BENDS	241
	TR(2,K,2)=(STRT(K)-STRT(K-1))/(STNT(K)-STNT(K-1))	BENDS	242
	WRITE(6,16) I,SPLBMC,SYC	BENDS	243
	DO 38 J=1,K	BENDS	244
	38 WRITE(6,98) STRESS(J),STRAIN(J),TN(1,J,2),TR(1,J,2)	BENDS	245
245	WRITE(6,28) I,SPLBMT,SVT	BENDS	246
	DO 40 J=1,K	BENDS	247
	40 WRITE(6,98) STRT(J),STNT(J),TN(2,J,2),TR(2,J,2)	BENDS	248
	53 CONTINUE	BENDS	249
	WRITE(6,8)	BENDS	250
250	DO 44 I=1,NE	BENDS	251
	44 WRITE(6,7) EM(I),EO(I),Y(I),SIL(I)	BENDS	252
	IF(I.TS.EQ.0) GO TO 80	BENDS	253
	DO 79 I=1,NE	BENDS	254
	K=NPA(I)	BENDS	255
255	DO 59 J=1,K	BENDS	256
	STRESS(J)=ESRCRV(I,J,1)	BENDS	257
	STRAIN(J)=ESNCRV(I,J,1)	BENDS	258
	STRT(J)=ESPCRV(I,J,2)	BENDS	259
	59 STNT(J)=FSNCRV(I,J,2)	BENDS	260
260	IF(SIL(I).LT.0.0) SIL(I)=GETSTN(STRESS,STRAIN,NPTS,SIL(I))	BENDS	261
	IF(SIL(I).GT.0.0) SIL(I)=GETSTN(STRT,STNT,NPTS,SIL(I))	BENDS	262
	79 CONTINUE	BENDS	263
	80 CONTINUE	BENDS	264
265	C BEGIN CURVATURE ITERATION	BENDS	265
	DO 100 NEXT=1,IBENDS	BENDS	266
	RF=R=RADII(NEXT)	BENDS	267
	NEXT=NEXT	BENDS	268
	N=0	BENDS	269
270	F=0.5*R	BENDS	270
	42 R=0-F	BENDS	271
	N=N+1	BENDS	272
	NY=NS=0	BENDS	273
	IF(ITER.NE.0.AND.N.LE.15) WRITE(6,12) R,F	BENDS	274
275	IF(N.GT.15) GO TO 62	BENDS	275
	FY0=0.5*YCG	BENDS	276
	Y0=YCG	BENDS	277
	AM=CF=TF=0.0	BENDS	278
280	C CALCULATE STRAIN,STRESS AND MOMENT	BENDS	279
	52 Y0=Y0-FY0	BENDS	280
	NY=NY+1	BENDS	281
	IF(NEXT.EQ.1) C=1.0/(R+Y0)	BENDS	282
	IF(NEXT.NE.1) C=1.0/(R+Y0)-1.0/(RADII(NEXT-1)+YCG)	BENDS	283
285	DO 51 I=1,NE	BENDS	284
		BENDS	285
		BENDS	286

PROGRAM BENDS

74/74

OPT=0 ROUND=0/ TRACE

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	IPTS=NPA(I)	BENDS	287
	Q=Y(I)-Y0	BENDS	288
	ESTN(I)=C*0	BENDS	289
290	ESTN(I)=E*STN(I)+SIL(I)	BENDS	290
	M=1	BENDS	291
	IF(ESTN(I).GT.0.0) M=2	BENDS	292
	DO 43 J=1,IPTS	BENDS	293
	STRM(J)=ESRCRV(I,J,M)	BENDS	294
295	43 STNM(J)=ESMCRV(I,J,M)	BENDS	295
	STR(I)=S(STPM,STNM,IPTS,ESTN(I))	BENDS	296
	T=STR(I)*EW(I)*ED(I)	BENDS	297
	IF(T.LE.0.0) CF=CF+T	BENDS	298
	IF(T.GT.0.0) TF=TF+T	BENDS	299
300	AM=AM+T*0	BENDS	300
	51 CONTINUE	BENDS	301
	C	BENDS	302
	C CHECK EQUILIBRIUM OF FORCES	BENDS	303
	CF=ABS(CF)	BENDS	304
	TF=ABS(TF)	BENDS	305
305	U=ABS(CF-TF)	BENDS	306
	V=ABS(CF+TF)/2.0	BENDS	307
	YS9=Y0	BENDS	308
	IF(IX.NE.0.AND.NY.LE.10) WRITE(6,13) Y0,FY0,CF,TF	BENDS	309
	IF(NY.GT.10) GO TO 62	BENDS	310
310	IF((U/V).LT.0.02) GO TO 69	BENDS	311
	IF(CF.LT.TF) Y0=Y0+FY0	BENDS	312
	FY0=FY0/2.0	BENDS	313
	AM=CF=TF=0.0	BENDS	314
	GO TO 52	BENDS	315
315	C	BENDS	316
	C CALCULATE NEUTRAL AXIS AFTER SPRINGBACK	BENDS	317
	69 CF=TF=TEST=0.0	BENDS	318
	MS=0	BENDS	319
	FSB=YCG-Y0	BENDS	320
320	61 YSB=YSB+FSB	BENDS	321
	MS=MS+1	BENDS	322
	CSB=1.0/(R+Y0)-1.0/(R+YSB)	BENDS	323
	DO 60 I=1,NE	BENDS	324
	IF(KBE.GT.19) GO TO 45	BENDS	325
325	CALL BE(STR(I),NPA(I),I,STRBE,STNBE,STRM,STNM,SPLF,SUF)	BENDS	326
	GO TO 83	BENDS	327
	45 CALL BEX(I,STRBE,STNBE,STRM,STNM,NPA(I),IPTS,STR(I),KBE)	BENDS	328
	83 DO 42 J=1,IPTS	BENDS	329
	TR(I,J,1)=STRBE(J)	BENDS	330
330	TN(I,J,1)=STNBE(J)	BENDS	331
	TR(I,J,2)=STRM(J)	BENDS	332
	82 TN(I,J,2)=STNM(J)	BENDS	333
	NPAT(I)=IPTS	BENDS	334
	Q=YSB-Y(I)	BENDS	335
335	SBN(I)=CSB*0	BENDS	336
	IF(SBN(I).GT.0.0) SBS(I)=S(STRM,STNM,IPTS,SBN(I))	BENDS	337
	IF(SBN(I).LE.0.0) SBS(I)=S(STRBE,STNBE,IPTS,SBN(I))	BENDS	338
	STN=STR(I)/E	BENDS	339
	C	BENDS	340
340	C ADD ELASTIC STRAIN NEEDED TO RECOVER FROM INITIAL BEND TO STRAIN	BENDS	341
	C DUE TO SPRINGBACK AND USE SUM TO GET FINAL STRESS	BENDS	342
	TS(I)=STN+SBN(I)	BENDS	343

		IF(TS(I).GT.0.0) TSTR(I)=S(STRM,STNM,IPTS,TS(I))	BENDS	344
		IF(TS(I).LE.0.0) TSTR(I)=S(STRBF,STNBE,IPTS,TS(I))	BENDS	345
345		IF(TSTR(I).LT.0.0) CF=CF+TSTR(I)*EW(I)*ED(I)	BENDS	346
		IF(TSTR(I).GT.0.0) TF=TF+TSTR(I)*EW(I)*ED(I)	BENDS	347
	61	CONTINUE	BENDS	348
	C		BENDS	349
	C	CHECK SUM OF FORCES	BENDS	350
350		CF=ABS(CF)	BENDS	351
		TF=ABS(TF)	BENDS	352
		U=ABS(CF-TF)	BENDS	353
		V=ABS(CF+TF)/2.0	BENDS	354
		IF(ITR.NE.0.AND.NS.LE.10) WRITE(6,21) YSB,FSB,CF,TF	BENDS	355
355		IF(NS.GT.10) GO TO 62	BENDS	356
		IF((U/V).LT.0.02) GO TO 54	BENDS	357
		IF(CF.LT.TF) YSB=YSB-FSB	BENDS	358
		IF(CF.LT.TF.AND.YSB.GT.YCG) TEST=1.0	BENDS	359
360		IF(TEST.EQ.0.0.AND.YSB.GT.YCG) FSB=FSB*2.0	BENDS	360
		FSB=FSB/2.0	BENDS	361
		CF=TF*0.0	BENDS	362
		GO TO 61	BENDS	363
	C		BENDS	364
	C	CHECK SUM OF MOMENTS	BENDS	365
365	54	CM=TM*0.0	BENDS	366
		DO 56 J=1,NF	BENDS	367
		XH=TSTR(J)*EW(J)*ED(J)*(Y(J)-YSB)	BENDS	368
		IF(XH.LT.0.0) CM=CM+XH	BENDS	369
		IF(XH.GT.0.0) TM=TM+XH	BENDS	370
370	56	CONTINUE	BENDS	371
		CM=ABS(CM)	BENDS	372
		TM=ABS(TM)	BENDS	373
		U=ABS(CM-TM)	BENDS	374
		V=ABS(CM+TM)/2.0	BENDS	375
375		IF(ITR.NE.0.AND.NS.LE.10) WRITE(6,6) CM,TM	BENDS	376
		IF((U/V).LT.0.02) GO TO 41	BENDS	377
		IF(CM.GT.TM) R=R+F	BENDS	378
		F=F/2.0	BENDS	379
380		GO TO 42	BENDS	380
	C		BENDS	381
	C	END OF CURRENT RADIUS ITERATION	BENDS	382
	41	DO 84 I=1,NF	BENDS	383
		J=NPA(I)=NPAT(I)	BENDS	384
		SIL(I)=TS(I)	BENDS	385
385		DO 84 K=1,J	BENDS	386
		FSRCRV(I,K,1)=TR(I,K,1)	BENDS	387
		ESNCRV(I,K,1)=TN(I,K,1)	BENDS	388
		FSRCRV(I,K,2)=TR(I,K,2)	BENDS	389
390	84	ESNCRV(I,K,2)=TN(I,K,2)	BENDS	390
		YCG=YSB	BENDS	391
		IF(IEBUGR.GE.0) GO TO 65	BENDS	392
		WRITE(6,96) MEXT	BENDS	393
		DO 50 M=1,2	BENDS	394
		DO 50 I=1,NF	BENDS	395
395		IPTS=NPA(I)	BENDS	396
	50	WRITE(6,93) (FSRCRV(I,J,M),ESNCRV(I,J,M),J=1,IF'S)	BENDS	397
	65	WRITE(6,27) MEXT,RADII(MEXT),R,YSB,YD,AM	BENDS	398
		WRITE(6,9) MEXT,IBENDS,RF	BENDS	399
		DO 102 L=1,NE	BENDS	400

PROGRAM BENDS 74/74 OPT=0 ROUND=0/ TRACE FTM 4.50414 09/29/76 11.04.43

400	102 WRITE(6,10) L,Y(L),ESTN(L),STR(L),SON(L),SBS(L),TS(L),TSTR(L)	BENDS	401
	C	BENDS	402
	C CHECK EQUILIBRIUM OF FINAL RESIDUAL STRESS DISTRIBUTION	BENDS	403
	W=X=0.0	BENDS	404
	DO 55 I=1,NE	BENDS	405
405	W=W+TSTR(I)*EW(I)*ED(I)	BENDS	406
	55 X=X+TSTR(I)*EW(I)*ED(I)*Y(I)	BENDS	407
	WRITE(6,29) W,X	BENDS	408
	100 CONTINUE	BENDS	409
	C	BENDS	410
410	C COMPUTE EFFECTIVE STRESS-STRAIN CURVES FOR ENTIRE FRAME	BENDS	411
	CALL FRMCRV(TSTR,NPA,E,EW,ED,AFRAME,DEBUGR,NE,STRNK,FABSTR)	BENDS	412
	IF(MODSOD.NE.0) CALL FORCRV (FABSTR,STRNK,INEX,NFE,NME)	BENDS	413
	STOP	BENDS	414
	62 WRITE(6,22) N,NV,NS,CF,TF	BENDS	415
415	WRITE(6,9) NEXT,INENDS,RF	BENDS	416
	DO 70 I=1,NE	BENDS	417
	70 WRITE(6,10) I,Y(I),ESTN(I),STR(I),SON(I),SBS(I),TS(I),TSTR(I)	BENDS	418
	IF(DEBUGR.EQ.0) STOP	BENDS	419
	WRITE(6,99)	BENDS	420
420	DO 89 M=1,2	BENDS	421
	DO 89 I=1,NE	BENDS	422
	IPTS=NFEAT(I)	BENDS	423
	89 WRITE(6,93) (TR(I,J,M),TN(I,J,M),J=1,IPTS)	BENDS	424
	STOP	BENDS	425
425	END	BENDS	426

SUBROUTINE BE

74/74

OPT=0 ROUND=0/ TRACE

FTN 4.5+414

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1		SUBROUTINE BE (A,NPTS,L,STRC,STNC,STRT,STNT,SPLF,SUF)	BE	2
	C		BE	3
	C	PROGRAM TO COMPUTE BAUSCHINGER EFFECT AS A COMBINATION OF	BE	4
	C	KINEMATIC AND ISOTROPIC HARDENING RULES. DEFAULT VALUES	BE	5
5	C	OF FACTORS PRODUCE FULL KINEMATIC REDUCTION IN THE PROPORTIONAL	BE	6
	C	LIMIT WITH NO CHANGE IN THE ULTIMATE LIMIT	BE	7
	C		BE	8
		COMMON /AA/ ESRCRV(50,50,2),ESNCRV(50,50,2)	BE	9
		DIMENSION STRC(50),STNC(50),STRT(50),STNT(50),STRESS(50)	BE	10
10		DIMENSION STRAIN(50)	BE	11
		M=1	BE	12
		IF(A.GT.0.0) M=2	BE	13
		DO 1 I=1,NPTS	BE	14
		STRESS(I)=ESRCRV(L,I,M)	BE	15
15	1	STRAIN(I)=ESNCRV(L,I,M)	BE	16
		STN=GETSTN(STRESS,STRAIN,NPTS,A)	BE	17
		B=GETPL(STRESS,STRAIN,NPTS,L)	BE	18
		PLSN=GETSTN(STRESS,STRAIN,NPTS,B)	BE	19
		PSTN=AES(STN)	BE	20
20		STRC(1)=STNC(1)=STRT(1)=STNT(1)=0.0	BE	21
		DO 11 I=2,NPTS	BE	22
		STNC(I)=ESRCRV(L,I,1)	BE	23
		STNC(I)=ESNCRV(L,I,1)	BE	24
		STRT(I)=ESRCRV(L,I,2)	BE	25
25	11	STNT(I)=ESNCRV(L,I,2)	BE	26
		IF(PSTN.LE.PLSN) RETURN	BE	27
		E=B/PLSN	BE	28
		SNRMAX=(ABS(A)-B)/E	BE	29
		IF(A.GT.0.0) GO TO 30	BE	30
30	C		BE	31
	C	PRESTRAIN IS COMPRESSIVE	BE	32
		F=GETPL(STRT,STNT,NPTS,L)	BE	33
		G=GETSTN(STRT,STNT,NPTS,F)	BE	34
		E=F/G	BE	35
35		D=STNT(NPTS)-G	BE	36
		DO 20 I=2,NPTS	BE	37
		SNU=SNRMAX*(STNT(I)-G)/D*SUF	BE	38
		SRU=SNU*E	BE	39
		SNP=SNRMAX*(STNT(NPTS)-STNT(I))/D*SPLF	BE	40
40		SRP=SNP*E	BE	41
		STRT(I)=STRT(I)-SRP+SRU	BE	42
	20	STNT(I)=STNT(I)-SNP+SNU	BE	43
		CALL STNHRD(A,STRC,STNC,NPTS,PSTN)	BE	44
		RETURN	BE	45
45	C		BE	46
	C	PRESTRAIN IS TENSILE	BE	47
	30	F=GETPL(STRC,STNC,NPTS,L)	BE	48
		G=GETSTN(STRC,STNC,NPTS,F)	BE	49
		E=F/G	BE	50
50		D=STNC(NPTS)-G	BE	51
		DO 31 I=2,NPTS	BE	52
		SNU=SNRMAX*(STNC(I)-G)/D*SUF	BE	53
		SRU=SNU*E	BE	54
		SNP=SNRMAX*(STNC(NPTS)-STNC(I))/D*SPLF	BE	55
55		SRP=SNP*E	BE	56
		STRC(I)=STRC(I)-SRP+SRU	BE	57
	31	STNC(I)=STNC(I)-SNP+SNU	BE	58

SUBROUTINE BE

74/74 OPT=0 ROUND=0/ TRACE

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CALL STNRD(A,STRT,STNT,NPTS,PSTN)
RETURN
END

BE 59
BE 60
BE 61

60

1		SUBROUTINE BEX(L,STRBE,STNBE,STRM,STNM,NPTS,IPTS,A,KBE)	BEX	2
	C		BEX	3
	C	PROGRAM TO PRODUCE A BAUSCHINGER EFFECT ELEMENTAL STRESS-STRAIN	BEX	4
	C	CURVE FROM NONDIMENSIONALIZED EXPERIMENTAL DATA	BEX	5
5			BEX	6
	C	COMMON /AA/ ESRCRV(50,50,2),ESNCRV(50,50,2)	BEX	7
	C	COMMON /MATDAT/ CCA,TCA,CCI,TCI,NPTAC,NPTAT,CNA,TNA,NC,NT	BEX	8
	C	DIMENSION STRBE(50),STNBE(50),STRM(50),STNM(50),STRESS(50)	BEX	9
	C	DIMENSION STRAIN(50),CCA(50,50),TCA(50,50),CNA(50,50),TNA(50,50)	BEX	10
10		DIMENSION CCI(50),TCI(50),NPTAC(50),NPTAT(50)	BEX	11
	C	DIMENSION SRC(50),SNC(50),SRT(50),SNT(50)	BEX	12
	C	GET PRESTRAIN	BEX	13
	C	M=1	BEX	14
15		IF(A.GT.0.0) M=2	BEX	15
	C	DO 30 I=1,NPTS	BEX	16
	C	STRESS(I)=ESRCRV(L,I,M)	BEX	17
	C	30 STRAIN(I)=ESNCRV(L,I,M)	BEX	18
	C		BEX	19
20		DEFINE ELEMENTAL BAUSCHINGER EFFECT CURVES	BEX	20
	C	DO 12 I=1,NPTS	BEX	21
	C	SRC(I)=ESRCRV(L,I,1)	BEX	22
	C	SNC(I)=ESNCRV(L,I,1)	BEX	23
	C	SRT(I)=ESRCRV(L,I,2)	BEX	24
25		12 SNT(I)=ESNCRV(L,I,2)	BEX	25
	C	IF(KBE.EQ.21) CALL HSSCL(SRC,SNC,SRT,SNT,NPTS,0)	BEX	26
	C	IF(KBE.EQ.22) CALL HSSPT(SRC,SNC,SRT,SNT,NPTS,0)	BEX	27
	C	STN=GETSTN(STRESS,STRAIN,NPTS,A)	BEX	28
	C	R=GETPL(STRESS,STRAIN,NPTS,L)	BEX	29
30		PLSN=GETSTN(STRESS,STRAIN,NPTS,B)	BEX	30
	C	PSTN=ABS(STN)	BEX	31
	C	RATIO=STRBE(1)=STNBE(1)=STRM(1)=STNM(1)=0.0	BEX	32
	C	IF(PSTN.GT.PLSN) GO TO 10	BEX	33
35		PRESTRAIN IS LESS THAN THE PROPORTIONAL LIMIT	BEX	34
	C	IPTS=NPTS	BEX	35
	C	DO 11 I=2,IPTS	BEX	36
	C	STRBE(I)=ESRCRV(L,I,1)	BEX	37
	C	STNBE(I)=ESNCRV(L,I,1)	BEX	38
40		STRM(I)=ESRCRV(L,I,2)	BEX	39
	C	11 STNM(I)=ESNCRV(L,I,2)	BEX	40
	C	RETURN	BEX	41
	C	10 IF(STN.GT.0.0) GO TO 30	BEX	42
45		PRESTRAIN IS COMPRESSIVE	BEX	43
	C	DO 21 I=2,NT	BEX	44
	C	IF(PSTN.GE.TCI(I)) GO TO 21	BEX	45
	C	RATIO=(PSTN-TCI(I-1))/(TCI(I)-TCI(I-1))	BEX	46
	C	K=I	BEX	47
50		GO TO 22	BEX	48
	C	21 CONTINUE	BEX	49
	C	IF(RATIO.EQ.0.0) GO TO 24	BEX	50
	C	22 IPTS=NPTAT(K)	BEX	51
	C	OS=(STRAIN(IPTS)-STRAIN(2))/(FLOAT(IPTS)-2.0)	BEX	52
55		STRBE(2)=STRESS(2)	BEX	53
	C	STNBE(2)=STRAIN(2)	BEX	54
	C	DO 26 I=3,IPTS	BEX	55
	C		BEX	56
	C		BEX	57
	C		BEX	58

		STNBE(I)=STNBE(I-1)*DS	BEX	59
60	26	STRBE(I)=S(STRESS,STRAIN,NPTS,STNBE(I))	BEX	60
		DO 23 I=2,IPTS	BEX	61
		STRM(I)=TCA(I,K-1)+RATIO*(TCA(I,K)-TCA(I,K-1))	BEX	62
	23	STNM(I)=TNA(I,K-1)+RATIO*(TNA(I,K)-TNA(I,K-1))	BEX	63
		CALL STNHRD(A,STRBE,STNBE,IPTS,PSTN)	BEX	64
		RETURN	BEX	65
65	C		BEX	66
	C	PRESTRAIN IS GREATER THAN HIGHEST AVAILABLE EXPERIMENTAL DATA	BEX	67
	24	IPTS=NFTAT(NT)	BEX	68
		DS=(STRAIN(NPTS)-STRAIN(2))/(FLOAT(IPTS)-2.0)	BEX	69
		STRM(2)=STRESS(2)	BEX	70
70		STNBE(2)=STRAIN(2)	BEX	71
		DO 27 I=3,IPTS	BEX	72
		STNBE(I)=STNBE(I-1)*DS	BEX	73
	27	STRBE(I)=S(STRESS,STRAIN,NPTS,STNBE(I))	BEX	74
		DO 25 I=2,IPTS	BEX	75
75		STRM(I)=TCA(I,NT)	BEX	76
	25	STNM(I)=TNA(I,NT)	BEX	77
		CALL STNHRD(A,STRBE,STNBE,IPTS,PSTN)	BEX	78
		RETURN	BEX	79
80	C		BEX	80
	C	PRESTRAIN IS TENSILE	BEX	81
	30	DO 31 I=2,NC	BEX	82
		IF(PSTN.GE.CCI(I)) GO TO 31	BEX	83
		RATIO=(PSTN-CCI(I-1))/(CCI(I)-CCI(I-1))	BEX	84
		K=I	BEX	85
85		GO TO 32	BEX	86
	31	CONTINUE	BEX	87
		IF(RATIO.EQ.0.0) GO TO 34	BEX	88
	32	IPTS=NFTAC(K)	BEX	89
		DS=(STRAIN(NPTS)-STRAIN(2))/(FLOAT(IPTS)-2.0)	BEX	90
90		STRM(2)=STRESS(2)	BEX	91
		STNM(2)=STRAIN(2)	BEX	92
		DO 36 I=3,IPTS	BEX	93
		STNM(I)=STNM(I-1)*DS	BEX	94
95	36	STRM(I)=S(STRESS,STRAIN,NPTS,STNM(I))	BEX	95
		DO 33 I=2,IPTS	BEX	96
		STRBE(I)=CCA(I,K-1)+RATIO*(CCA(I,K)-CCA(I,K-1))	BEX	97
	33	STNBE(I)=CNA(I,K-1)+RATIO*(CNA(I,K)-CNA(I,K-1))	BEX	98
		CALL STNHRD(A,STRM,STNM,IPTS,PSTN)	BEX	99
		RETURN	BEX	100
100	C		BEX	101
	C	PRESTRAIN IS GREATER THAN HIGHEST AVAILABLE EXPERIMENTAL DATA	BEX	102
	34	IPTS=NFTAC(NC)	BEX	103
		DS=(STRAIN(NPTS)-STRAIN(2))/(FLOAT(IPTS)-2.0)	BEX	104
		STRM(2)=STRESS(2)	BEX	105
105		STNM(2)=STRAIN(2)	BEX	106
		DO 37 I=3,IPTS	BEX	107
		STNM(I)=STNM(I-1)*DS	BEX	108
	37	STRM(I)=S(STRESS,STRAIN,NPTS,STNM(I))	BEX	109
		DO 35 I=2,IPTS	BEX	110
110		STRBE(I)=CCA(I,NC)	BEX	111
	35	STNBE(I)=CNA(I,NC)	BEX	112
		CALL STNHRD(A,STRM,STNM,IPTS,PSTN)	BEX	113
		RETURN	BEX	114
		END	BEX	115

1		SUBROUTINE FRMCRV(RES,NPA,E,EN,EO,AFRAME,DEBUGR,ME,STRNK,FABSTRI)	FRMCRV	2
	C		FRMCRV	3
	C	PROGRAM TO ADD EFFECTS OF RESIDUAL STRESS TO ELEMENT CURVES	FRMCRV	4
	C	AND PRODUCE AVERAGE FRAME STRESS-STRAIN CURVE	FRMCRV	5
5		COMMON /AA/ ESRCRV(50,50,2),ESNCRV(50,50,2)	FRMCRV	6
		DIMENSION RES(50),STRS(50),STRN(50),STR(50),STN(50),EN(50)	FRMCRV	7
		DIMENSION ED(50),NPA(50)	FRMCRV	8
		INTEGER DEBUGR	FRMCRV	9
10		21 FORMAT(3X,F10.0,10X,F8.6,10X,E13.6,6X,E13.6)	FRMCRV	10
		22 FORMAT(*EFFECTIVE STRESS-STRAIN CURVE INCLUDING*/ RESIDUAL STRES	FRMCRV	11
		1S AND RAUSCHINGER EFFECT*/ WITH *,F7.0,* FABRICATION STRESS*/5X,	FRMCRV	12
		2*STRESS*,14X,*STRAIN*,16X,*ES*,10X,*ET*/)	FRMCRV	13
		23 FORMAT(*EFFECTIVE STRESS-STRAIN CURVE BEFORE RESIDUAL STRESS EFFECT FOR ELE	FRMCRV	14
15		1MENT*,13//6X,*STRESS*,14X,*STRAIN*/)	FRMCRV	15
		24 FORMAT(*RESIDUAL STRESS IS*,F10.0,4X,*CORRESPONDING STRAIN IS *,	FRMCRV	16
		1F7.4)	FRMCRV	17
		25 FORMAT(*EFFECTIVE STRESS-STRAIN CURVE ACCOUNTING FOR R.S. AND B.E. FOR ELEM	FRMCRV	18
		1ENT *,13//6X,*STRESS*,14X,*STRAIN*/)	FRMCRV	19
20		26 FORMAT(*EFFECTIVE STRESS-STRAIN CURVE USED TO COMPUTE EFFECTIVE FRAME CURVE	FRMCRV	20
		1 FOR ELEMENT *,13//6X,*STRESS*,14X,*STRAIN*/)	FRMCRV	21
		27 FORMAT(5(5X,F10.0,2X,F8.6))	FRMCRV	22
		28 FORMAT(*EFFECTIVE STRESS-STRAIN CURVES INCORPORATING B.E. AND R.S.*	FRMCRV	23
		1//)	FRMCRV	24
25		STRS(1)=STRN(1)=STR(1)=STN(1)=0.0	FRMCRV	25
		DO 1 I=1,NE	FRMCRV	26
		A=RES(I)	FRMCRV	27
		C=0.0	FRMCRV	28
		NPTS=NPA(I)	FRMCRV	29
30		DO 2 J=2,NPTS	FRMCRV	30
		STR(J)=ESRCRV(I,J,1)	FRMCRV	31
		2 STN(J)=ESNCRV(I,J,1)	FRMCRV	32
		IF(I.NE.DEBUGR) GO TO 12	FRMCRV	33
		WRITE(6,23) I	FRMCRV	34
35		DO 14 K=1,NPTS	FRMCRV	35
		14 WRITE(6,21) STR(K),STN(K)	FRMCRV	36
		12 IF(A.GT.0.0) GO TO 3	FRMCRV	37
	C		FRMCRV	38
	C	COMPRESSIVE RESIDUAL STRESS	FRMCRV	39
40		R=GETSTN(STR,STN,NPTS,A)	FRMCRV	40
		DO 11 J=2,50	FRMCRV	41
		STRN(J)=C=C+STRNK	FRMCRV	42
		D=ABS(B)+C	FRMCRV	43
45		11 STRS(J)=S(STR,STN,NPTS,D)+A	FRMCRV	44
		GO TO 4	FRMCRV	45
	C		FRMCRV	46
	C	TENSILE RESIDUAL STRESS UNLOADS ELASTICALLY, UNTIL ELEMENT GOES	FRMCRV	47
	C	INTO COMPRESSION	FRMCRV	48
50		3 B=A/E	FRMCRV	49
		DO 5 J=2,50	FRMCRV	50
		STRN(J)=C=C+STRNK	FRMCRV	51
		IF(C.LE.B) STRS(J)=F*C	FRMCRV	52
		7=C-B	FRMCRV	53
		IF(C.GT.A) STRS(J)=S(STR,STN,NPTS,D)+A	FRMCRV	54
55		5 CONTINUE	FRMCRV	55
		4 DO 6 J=1,50	FRMCRV	56
		ESRCRV(I,J,1)=STRS(J)	FRMCRV	57
			FRMCRV	58

SUBROUTINE FRMCRV 74/74 OPT=0 ROUND=0/ TRACE

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	6	ESNCRV(I,J,1)=STRN(J)	FRMCRV	59
		IF(I.NE.DEBUGR) GO TO 1	FRMCRV	60
60		WRITE(6,24) A,B	FRMCRV	61
		WRITE(6,25) I	FRMCRV	62
		DO 16 J=1,50	FRMCRV	63
	16	WRITE(6,21) STRS(J),STRN(J)	FRMCRV	64
	1	CONTINUE	FRMCRV	65
65	C		FRMCRV	66
	C	INDIVIDUAL ELEMENT CURVES NOW INCORPORATE B.E. AND R.S.	FRMCRV	67
		IF(DEBUGR.GE.0) GO TO 19	FRMCRV	68
		WRITE(6,28)	FRMCRV	69
		DO 20 I=1,NE	FRMCRV	70
70	20	WRITE(6,27) (ESRCRV(I,J,1),ESNCRV(I,J,1),J=1,50)	FRMCRV	71
	19	CONTINUE	FRMCRV	72
		STRS(1)=STRN(1)=0.0	FRMCRV	73
		C=0.0	FRMCRV	74
		I=1	FRMCRV	75
75	7	I=I+1	FRMCRV	76
		B=0.0	FRMCRV	77
		STRN(I)=C+C*STANK	FRMCRV	78
		J=0	FRMCRV	79
	8	J=J+1	FRMCRV	80
80		DO 9 K=1,50	FRMCRV	81
		STR(K)=ESRCRV(J,K,1)	FRMCRV	82
	9	STN(K)=ESNCRV(J,K,1)	FRMCRV	83
		IF(DEBUGR.LE.0) GO TO 17	FRMCRV	84
		IF(J.NF.DEBUGR.OR.I.NE.2) GO TO 17	FRMCRV	85
85		WRITE(6,26) J	FRMCRV	86
		DO 18 K=1,50	FRMCRV	87
	18	WRITE(6,21) STR(K),STN(K)	FRMCRV	88
	17	CONTINUE	FRMCRV	89
	C		FRMCRV	90
90	C	SUM AREA WEIGHTED STRESSES TO GET AVERAGE STRESS	FRMCRV	91
		A=S(STR,STN,50,C)*EM(I)*ED(I)/AFRAME	FRMCRV	92
		B=B+A	FRMCRV	93
		IF(J.LT.NE) GO TO 8	FRMCRV	94
		STRS(I)=B	FRMCRV	95
95		IF(I.LT.50) GO TO 7	FRMCRV	96
		WRITE(6,22) FABSTR	FRMCRV	97
		L=50	FRMCRV	98
		IF(FABSTR.NE.0.0) CALL FAB(STRS,STRN,FABSTR,L)	FRMCRV	99
		CALL PNTOUT(STRS,STRN,L)	FRMCRV	100
100		DO 15 I=2,L	FRMCRV	101
		STN(I)=(STRS(I)/STRN(I))	FRMCRV	102
		IF(I.EQ.L) GO TO 15	FRMCRV	103
		STR(I)=(STRS(I+1)-STRS(I-1))/(STN(I+1)-STN(I-1))	FRMCRV	104
	15	CONTINUE	FRMCRV	105
105		STN(1)=0.0	FRMCRV	106
		STR(1)=STRS(2)/STRN(2)	FRMCRV	107
		STR(L)=(STRS(L)-STRS(L-1))/(STN(L)-STN(L-1))	FRMCRV	108
		DO 10 I=1,L	FRMCRV	109
110	10	WRITE(6,21) STRS(I),STRN(I),STN(I),STR(I)	FRMCRV	110
		RETURN	FRMCRV	111
		END	FRMCRV	112

SUBROUTINE FORCRV 74/74 OPT=0 ROUND=0/ TRACE

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1		SUBROUTINE FORCRV (FABSTR,STRNK,INEX,NFE,NWE)	FORCRV	2
	C		FORCRV	3
	C	PROGRAM TO PRODUCE STRESS-STRAIN CURVES FOR MOD-MOD BRYANT	FORCRV	4
	C		FORCRV	5
5		COMMON /AA/ ESRCRV(50,50,2),ESNCRV(50,50,2)	FORCRV	6
		DIMENSION STRN(50,4),AVG(50,4),NP(4)	FORCRV	7
		DIMENSION STR(50),STN(50)	FORCRV	8
		11 FORMAT('STRESS-STRAIN CURVES FOR MOD-MOD BRYANT'/' WITH A FABRICA	FORCRV	9
		TION STRESS OF ',F10.0///10X,'SEG. 1',	FORCRV	10
10		216X,'SEG. 2',16X,'SEG. 3',16X,'FLANGE'//4X,'STRESS',4X,'STRAIN',	FORCRV	11
		36X,'STRESS',4X,'STRAIN',6X,'STRESS',4X,'STRAIN',6X,'STRESS',4X,	FORCRV	12
		4,'STRAIN'//)	FORCRV	13
		12 FORMAT(1H)	FORCRV	14
		13 FORMAT('NUMBER OF ELEMENTS MUST BE A MULTIPLE OF FOUR TO '/' OBT	FORCRV	15
15		AIN CURVES FOR THE REVISED MODIFIED BRYANT PROGRAM ')	FORCRV	16
		14 FORMAT(1H,3X,F8.0,2X,F8.6)	FORCRV	17
		15 FORMAT(1H,25X,F8.0,2X,F8.6)	FORCRV	18
		16 FORMAT(1H,47X,F8.0,2X,F8.6)	FORCRV	19
		17 FORMAT(1H,69X,F8.0,2X,F8.6)	FORCRV	20
20		NUM=NFE+NWE	FORCRV	21
		K=NUM/4*	FORCRV	22
		IF(K.EQ.NUM) GO TO 21	FORCRV	23
		WRITE(6,13)	FORCRV	24
		RETURN	FORCRV	25
25		21 DO 22 I=1,50	FORCRV	26
		IFIN=0	FORCRV	27
		DO 23 J=1,4	FORCRV	28
		TOTAL=0.0	FORCRV	29
		ISTART=IFIN+1	FORCRV	30
30		L=NWE/4	FORCRV	31
		IF(INEX.LE.0.AND.J.EQ.1) L=NFE	FORCRV	32
		IF(INEX.GT.0.AND.J.EQ.4) L=NFE	FORCRV	33
		IFIN=IFIN+L	FORCRV	34
		DO 24 K=ISTART,IFIN	FORCRV	35
35		24 TOTAL=TOTAL+ESRCRV(K,I,1)	FORCRV	36
		23 AVG(I,J)=TOTAL/FLOAT(L)	FORCRV	37
		22 CONTINUE	FORCRV	38
		XKONT=-STRNK	FORCRV	39
		DO 25 I=1,50	FORCRV	40
40		XKONT=XKONT+STRNK	FORCRV	41
		DO 25 J=1,4	FORCRV	42
		25 STON(I,J)=XKONT	FORCRV	43
		DO 2 I=1,4	FORCRV	44
		DO 3 J=1,50	FORCRV	45
45		STR(J)=AVG(J,I)	FORCRV	46
		3 STN(J)=STN(J,I)	FORCRV	47
		IF(FABSTR.NE.0.0) CALL FAB(STR,STN,FABSTR,50)	FORCRV	48
		M=50	FORCRV	49
		CALL PNTOUT (STR,STN,M)	FORCRV	50
50		NP(I)=M	FORCRV	51
		DO 4 J=1,M	FORCRV	52
		AVG(J,I)=STR(J)	FORCRV	53
		4 STRN(J,I)=STN(J)	FORCRV	54
		2 CONTINUE	FORCRV	55
55		1 WRITE(6,11) FABSTR	FORCRV	56
		N=MAX0(NP(1),NP(2),NP(3),NP(4))	FORCRV	57
		DO 5 I=1,N	FORCRV	58

SUBROUTINE FORCRV 74/74 OPT=0 ROUND=0/ TRACE

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        WRITE(6,12)
        IF(INEX.LE.0) GO TO 6
60      IF(I.LE.NP(1)) WRITE(6,14) AVG(I,1),STRN(I,1)
        IF(I.LE.NP(2)) WRITE(6,15) AVG(I,2),STRN(I,2)
        IF(I.LE.NP(3)) WRITE(6,16) AVG(I,3),STRN(I,3)
        IF(I.LE.NP(4)) WRITE(6,17) AVG(I,4),STRN(I,4)
        GO TO 5
65      6 IF(I.LE.NP(4)) WRITE(6,14) AVG(I,4),STRN(I,4)
        IF(I.LE.NP(3)) WRITE(6,15) AVG(I,3),STRN(I,3)
        IF(I.LE.NP(2)) WRITE(6,16) AVG(I,2),STRN(I,2)
        IF(I.LE.NP(1)) WRITE(6,17) AVG(I,1),STRN(I,1)
70      5 CONTINUE
        RETURN
        END

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FORCRV 59
FORCRV 60
FORCRV 61
FORCRV 62
FORCRV 63
FORCRV 64
FORCRV 65
FORCRV 66
FORCRV 67
FORCRV 68
FORCRV 69
FORCRV 70
FORCRV 71
FORCRV 72

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SUBROUTINE FAB 74/74 OPT=0 ROUND=0/ TRACE

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1		SUBROUTINE FAB(STR,STN,FABSTR,L)	FAB	2
	C		FAB	3
	C	PROGRAM TO ACCOUNT FOR FIT-UP STRESS	FAB	4
	C		FAB	5
5		DIMENSION STR(50),STN(50)	FAB	6
		Q=SIGN(1.0,FABSTR)	FAB	7
		STR(1)=STN(1)=0.0	FAB	8
		M=L	FAB	9
		DO 101 J=2,M	FAB	10
10		IF(ABS(FABSTR).GT.STR(J)) GO TO 101	FAB	11
		R=(ABS(FABSTR)-STR(J-1))/(STR(J)-STR(J-1))	FAB	12
		FABSTN=R*(STN(J)-STN(J-1))+STN(J-1)	FAB	13
		L=L-J+2	FAB	14
		M=J-1	FAB	15
15		DO 102 K=2,L	FAB	16
		M=M+1	FAB	17
		STR(M)=STR(M)+FABSTR	FAB	18
	102	STN(K)=STN(M)+Q*FABSTN	FAB	19
		GO TO 100	FAB	20
20		101 CONTINUE	FAB	21
	100	RETURN	FAB	22
		END	FAB	23

FUNCTION GETSTN 74/74 OPT=0 ROUND=0/ TRACE

FTN 4.5+414

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1		FUNCTION GETSTN(STRESS,STRAIN,NPTS,STR)	GETSTN	2
	C		GETSTN	3
	C	PROGRAM TO CALCULATE STRAIN GIVEN A STRESS	GETSTN	4
	C		GETSTN	5
5		DIMENSION STRESS(50),STRAIN(50)	GETSTN	6
		DO 2 I=2,NPTS	GETSTN	7
		IF (ABS(STR).GT.STRESS(I)) GO TO 2	GETSTN	8
		RATIO=1.0-(STRESS(I)-ABS(STR))/(STRESS(I)-STRESS(I-1))	GETSTN	9
		F=SIGN(1.0,STR)	GETSTN	10
10		GETSTN=F*(STRAIN(I-1)+RATIO*(STRAIN(I)-STRAIN(I-1)))	GETSTN	11
		RETURN	GETSTN	12
	2	CONTINUE	GETSTN	13
		GETSTN=STRAIN(NPTS)	GETSTN	14
		RETURN	GETSTN	15
15		END	GETSTN	16

FUNCTION S

74/74 OPT=0 ROUND=0/ TRACE

FTN 4.50414

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1		FUNCTION S(STRESS,STRAIN,NPTS,ES)	S	2
	C		S	3
	C	PROGRAM TO GET STRESS FROM STRESS-STRAIN CURVE GIVEN ELASTIC STRAI	S	4
	C		S	5
5		DIMENSION STRESS(50),STRAIN(50)	S	6
		SIGU=STRESS(NPTS)*0.999	S	7
		F=SIGN(1.0,ES)	S	8
		STN=ABS(ES)	S	9
		IF(STN.LT.STRAIN(NPTS)) GO TO 1	S	10
10		S=SIGU*F	S	11
		RETURN	S	12
		1 DO 2 I=2,NPTS	S	13
		IF(STRAIN(I).GT.STN) GO TO 3	S	14
		2 CONTINUE	S	15
15		3 RATIO=1.0-(STRAIN(I)-STN)/(STRAIN(I)-STRAIN(I-1))	S	16
		S=F*(STRESS(I-1)+RATIO*(STRESS(I)-STRESS(I-1)))	S	17
		IF(ABS(S).GE.SIGU) S=F*SIGU	S	18
		RETURN	S	19
		END	S	20

FUNCTION GETPL

74/74 OPT=0 ROUND=0/ TRACE

FTN 4,5+414

09/29/76 11.04.43

1		FUNCTION GETPL(STR,STN,NPTS,ID)	GETPL	2
	C		GETPL	3
	C	PROGRAM TO FIND PROPORTIONAL LIMIT STRESS	GETPL	4
	C		GETPL	5
5		DIMENSION STR(50),STN(50)	GETPL	6
		11 FORMAT(*0PROPORTIONAL LIMIT NOT FOUND FOR ELEMENT *,I2//5X,*STRESS	GETPL	7
		1*,14X,*STRAIN*/)	GETPL	8
		12 FORMAT(13X,F10.0,10X,F8.6)	GETPL	9
		E=STR(2)/STN(2)	GETPL	10
10		DO 1 I=3,NPTS	GETPL	11
		A=STR(I)/STN(I)	GETPL	12
		B=ABS(E-A)/E	GETPL	13
		J=I	GETPL	14
		IF(B.GT.0.005) GO TO 2	GETPL	15
15		1 CONTINUE	GETPL	16
		GO TO 3	GETPL	17
		2 GETPL=STR(J-1)	GETPL	18
		RETURN	GETPL	19
		3 WRITE(6,11) ID	GETPL	20
20		DO 4 I=1,NPTS	GETPL	21
		4 WRITE(6,12) STR(I),STN(I)	GETPL	22
		STOP	GETPL	23
		END	GETPL	24

FUNCTION YPT		76/76	OPT=0 ROUND=0/ TRACE	FTN 4.5+414	09/29/76	11.04.43
1		FUNCTION YPT(STRESS,STRAIN,NPTS,XSTN)			YPT	2
	C				YPT	3
	C	CALCULATION OF A GIVEN PERCENT OFFSET STRESS			YPT	4
	C				YPT	5
5		DIMENSION STRESS(50),STRAIN(50)			YPT	6
		STR=GETPL(STRESS,STRAIN,NPTS,1)			YPT	7
		STN=GETSTN(STRESS,STRAIN,NPTS,STR)+0.002			YPT	8
		YPT=S(STRESS,STRAIN,NPTS,STN)			YPT	9
		RETURN			YPT	10
10		END			YPT	11

SUBROUTINE STNHRO 74/74 OPT=0 ROUND=0/ TRACE

FTN 4.50414

09/29/76 11.04.43

1		SUBROUTINE STNHRO (STR,STRBE,STNBE,IPTS,PSTN)	STNHRO	2
	C		STNHRO	3
	C	PROGRAM TO PRODUCE STRAIN HARDENED CURVE	STNHRO	4
	C		STNHRO	5
5		DIMENSION STRBE(50),STNBE(50),SR(50),SN(50)	STNHRO	6
		STRBE(1)=STNBE(1)=SR(1)=SN(1)=0.0	STNHRO	7
		E=STRBE(2)/STNBE(2)	STNHRO	8
		DO 1 J=1,IPTS	STNHRO	9
		SR(J)=STRBE(J)	STNHRO	10
10	1	SN(J)=STNBE(J)	STNHRO	11
		STRBE(2)=ABS(STR)*0.999	STNHRO	12
		STNBE(2)=STRBE(2)/E	STNHRO	13
		STNINC=(SN(IPTS)-SN(2))/(FLOAT(IPTS)-2.0)	STNHRO	14
		H=PSTN	STNHRO	15
15		DO 2 J=3,IPTS	STNHRO	16
		STNBE(J)=STNBE(J-1)+STNINC	STNHRO	17
		H=H+STNINC	STNHRO	18
	2	STRBE(J)=S(SR,SN,IPTS,H)	STNHRO	19
20		RETURN	STNHRO	20
		END	STNHRO	21

SUBROUTINE PNTOUT 74/74 OPT=0 ROUND=0/ TRACE

FTN 4.5+414

09/29/76 11.04.43

1		SUBROUTINE PNTOUT (STRS,STRN,NPTS)	PNTOUT	2
	C		PNTOUT	3
	C	PROGRAM TO REMOVE UNNECESSARY POINTS FROM STRESS-STRAIN CURVES	PNTOUT	4
	C		PNTOUT	5
5		DIMENSION STRS(50),STRN(50)	PNTOUT	6
		E=STRS(2)/STRN(2)	PNTOUT	7
		N=NPTS	PNTOUT	8
		I=0	PNTOUT	9
		1 I=I+1	PNTOUT	10
10		2 IF(I.EQ.(NPTS-1)) RETURN	PNTOUT	11
		ET1=(STRS(I+1)-STRS(I))/(STRN(I+1)-STRN(I))	PNTOUT	12
		IF(ET1.GT.(E*0.85)) GO TO 4	PNTOUT	13
		STRS(I+1)=STRS(I)	PNTOUT	14
		STRN(I+1)=STRN(I)	PNTOUT	15
15		NPTS=I+1	PNTOUT	16
		RETURN	PNTOUT	17
		4 P=0.20	PNTOUT	18
		IF(ET1.GT.(E*0.1)) P=0.10	PNTOUT	19
		IF(ET1.GT.(E*0.3)) P=0.02	PNTOUT	20
20		ET2=(STRS(I+2)-STRS(I+1))/(STRN(I+2)-STRN(I+1))	PNTOUT	21
		Q=(ET1-ET2)/ET1	PNTOUT	22
		IF(Q.GT.P) GO TO 1	PNTOUT	23
		L=NPTS-1	PNTOUT	24
		K=I+1	PNTOUT	25
25		DO 3 J=K,L	PNTOUT	26
		STRS(J)=STRS(J+1)	PNTOUT	27
		3 STRN(J)=STRN(J+1)	PNTOUT	28
		NPTS=NPTS-1	PNTOUT	29
		GO TO 2	PNTOUT	30
30		END	PNTOUT	31

1		SUBROUTINE HSSCL (STRESS,STRAIN,STRT,SYNT,NPTS,DEBUG)	HSSCL	2
	C		HSSCL	3
	C	DEFINITION OF MATERIAL PROPERTIES OF HIGH STRENGTH	HSSCL	4
	C	STEEL WITH A CURVILINEAR TYPE OF STRESS-STRAIN CURVE	HSSCL	5
5	C		HSSCL	6
		COMMON /MATDAT/ CCA,TCA,CCI,TCI,NPTAC,NPTAT,CNA,TNA,NC,NT	HSSCL	7
		DIMENSION CCA(50,5),TCA(50,5),CCI(5),TCI(5),NPTAC(5),NPTAT(5)	HSSCL	8
		DIMENSION STRESS(50),STRAIN(50),STRT(50),SYNT(50)	HSSCL	9
		DIMENSION CNA(50,5),TNA(50,5)	HSSCL	10
10		INTEGER DEBUGR	HSSCL	11
		11 FORMAT('0COMPRESSIVE STRESS-STRAIN CURVES AFFECTED BY PRESTRAIN *	HSSCL	12
		1 //4X,4('PRESTRAIN=',F7.4,6X)/3X,4('STRESS',5X,'STRAIN',6X)/)	HSSCL	13
		12 FORMAT(1X,4(F10.0,2X,F7.4,4X))	HSSCL	14
		13 FORMAT('0TENSILE STRESS-STRAIN CURVES AFFECTED BY PRESTRAIN *	HSSCL	15
15		1//4X,4('PRESTRAIN=',F7.4,6X)/3X,4('STRESS',5X,'STRAIN',6X)/)	HSSCL	16
		NC=NT=4	HSSCL	17
		NPTAC(1)=NPTAC(2)=NPTAC(3)=NPTAC(4)=24	HSSCL	18
		CCI(1)=0.0008CCI(2)=0.01008CCI(3)=0.02008CCI(4)=0.0350	HSSCL	19
		CNA(01)=0.008CNA(02)=1.008CNA(03)=2.008CNA(04)=3.008CNA(05)=4.00	HSSCL	20
20		CNA(06)=4.408CNA(07)=4.608CNA(08)=4.808CNA(09)=5.008CNA(10)=5.20	HSSCL	21
		CNA(11)=5.408CNA(12)=5.608CNA(13)=5.808CNA(14)=6.008CNA(15)=7.00	HSSCL	22
		CNA(16)=8.008CNA(17)=9.008CNA(18)=10.08CNA(19)=12.08CNA(20)=14.0	HSSCL	23
		CNA(21)=16.08CNA(22)=18.08CNA(23)=20.08CNA(24)=40.0	HSSCL	24
25		CCA(01,2)=1.0008CCA(02,2)=0.9008CCA(03,2)=0.8158CCA(04,2)=0.749	HSSCL	25
		CCA(05,2)=0.6938CCA(06,2)=0.6638CCA(07,2)=0.6628CCA(08,2)=0.661	HSSCL	26
		CCA(09,2)=0.6668CCA(10,2)=0.6708CCA(11,2)=0.6778CCA(12,2)=0.686	HSSCL	27
		CCA(13,2)=0.7028CCA(14,2)=0.7098CCA(15,2)=0.7568CCA(16,2)=0.801	HSSCL	28
		CCA(17,2)=0.8378CCA(18,2)=0.8758CCA(19,2)=0.9298CCA(20,2)=0.956	HSSCL	29
		CCA(21,2)=0.9708CCA(22,2)=0.9798CCA(23,2)=0.9938CCA(24,2)=1.024	HSSCL	30
30		CCA(01,3)=1.0008CCA(02,3)=0.8678CCA(03,3)=0.7488CCA(04,3)=0.677	HSSCL	31
		CCA(05,3)=0.6128CCA(06,3)=0.5828CCA(07,3)=0.5828CCA(08,3)=0.580	HSSCL	32
		CCA(09,3)=0.5798CCA(10,3)=0.5658CCA(11,3)=0.5888CCA(12,3)=0.591	HSSCL	33
		CCA(13,3)=0.6008CCA(14,3)=0.6088CCA(15,3)=0.6388CCA(16,3)=0.675	HSSCL	34
		CCA(17,3)=0.7068CCA(18,3)=0.7368CCA(19,3)=0.7858CCA(20,3)=0.824	HSSCL	35
35		CCA(21,3)=0.8608CCA(22,3)=0.8908CCA(23,3)=0.9108CCA(24,3)=0.992	HSSCL	36
		CCA(01,4)=1.0008CCA(02,4)=0.8678CCA(03,4)=0.7338CCA(04,4)=0.671	HSSCL	37
		CCA(05,4)=0.6038CCA(06,4)=0.5738CCA(07,4)=0.5718CCA(08,4)=0.573	HSSCL	38
		CCA(09,4)=0.5728CCA(10,4)=0.5728CCA(11,4)=0.5798CCA(12,4)=0.581	HSSCL	39
		CCA(13,4)=0.5908CCA(14,4)=0.5968CCA(15,4)=0.6298CCA(16,4)=0.656	HSSCL	40
40		CCA(17,4)=0.6818CCA(18,4)=0.7068CCA(19,4)=0.7518CCA(20,4)=0.784	HSSCL	41
		CCA(21,4)=0.8118CCA(22,4)=0.8368CCA(23,4)=0.8498CCA(24,4)=0.917	HSSCL	42
		DO 1 I=1,4	HSSCL	43
		NPTAT(I)=NPTAC(I)	HSSCL	44
45		1 TCI(I)=CCI(I)	HSSCL	45
		DO 3 I=1,24	HSSCL	46
		CNA(I,1)=TNA(I,1)=CNA(I,1)*0.001	HSSCL	47
		CCA(I,1)=S(STRESS,STRAIN,NPTS,CNA(I,1))	HSSCL	48
		3 TCA(I,1)=S(STRT,SYNT,NPTS,TNA(I,1))	HSSCL	49
		DO 2 I=1,24	HSSCL	50
50		DO 2 J=2,4	HSSCL	51
		TNA(I,J)=TNA(I,1)	HSSCL	52
		CNA(I,J)=CNA(I,1)	HSSCL	53
		TCA(I,J)=CCA(I,J)*TCA(I,1)	HSSCL	54
		2 CCA(I,J)=CCA(I,J)*CCA(I,1)	HSSCL	55
55		IF(DEBUGR.GE.0) RETURN	HSSCL	56
		WRITE(6,11) (CCI(I),I=1,4)	HSSCL	57
		WRITE(6,12) ((CCA(I,J),CNA(I,J),J=1,4),I=1,24)	HSSCL	58

SUBROUTINE HSSCL

74/74

OPT=0 ROUND=0/ TRACE

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60

WRITE(6,13) (TCI(I),I=1,4)
WRITE(6,12) ((TCA(I,J),TNA(I,J),J=1,4),I=1,24)
RETURN
END

HSSCL 59
HSSCL 60
HSSCL 61
HSSCL 62

SUBROUTINE HSSPT

74/74

OPT=0 ROUND=0/ TRACE

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1      SUBROUTINE HSSPT (STRESS,STRAIN,STRT,STNT,NPTS,DEBUGR)
C
C      DEFINITION OF MATERIAL PROPERTIES OF HIGH STRENGTH
C      STEEL WITH A PLATEAU TYPE STRESS-STRAIN CURVE
5      COMMON /MATDAT/ CCA,TCA,CCI,TCI,NPTAC,NPTAT,CNA,TNA,NC,NT
C
C      DIMENSION CCA(50,5),TCA(50,5),CCI(5),TCI(5),NPTAC(5),NPTAT(5)
C      DIMENSION STRESS(50),STRAIN(50),STRT(50),STNT(50)
C      DIMENSION CNA(50,5),TNA(50,5)
10     INTEGER DEBUGR
11     FORMAT(*COMPRESSIVE STRESS-STRAIN CURVES AFFECTED BY PRESTRAIN *)
12     FORMAT(1X,5(F10.0,2X,F7.4,4X))
13     FORMAT(*TENSILE STRESS-STRAIN CURVES AFFECTED BY PRESTRAIN *)
15     1//4X,5(*PRESTRAIN=*,F7.4,6X)/3X,5(*STRESS=*,5X,*STRAIN=*,6X)/)
C      NC=NT=5
C      NPTAC(1)=NPTAC(2)=NPTAC(3)=NPTAC(4)=NPTAC(5)=22
C      CCI(1)=0.08CCI(2)=0.003CCI(3)=0.0052CCI(4)=0.0086CCI(5)=0.016
C      CNA(01)=0.008CNA(02)=0.508CNA(03)=1.008CNA(04)=1.508CNA(05)=2.00
20     CNA(06)=2.508CNA(07)=3.008CNA(08)=3.508CNA(09)=4.008CNA(10)=4.50
C      CNA(11)=5.008CNA(12)=5.508CNA(13)=6.008CNA(14)=7.008CNA(15)=8.00
C      CNA(16)=9.008CNA(17)=10.008CNA(18)=11.008CNA(19)=12.008CNA(20)=15.0
C      CNA(21)=20.008CNA(22)=40.8
C      CCA(01,2)=1.0008CCA(02,2)=0.9028CCA(03,2)=0.9028CCA(04,2)=0.902
25     CCA(05,2)=0.9028CCA(06,2)=0.8968CCA(07,2)=0.8928CCA(08,2)=0.949
C      CCA(09,2)=1.0008CCA(10,2)=1.0178CCA(11,2)=1.0268CCA(12,2)=1.029
C      CCA(13,2)=1.0298CCA(14,2)=1.0308CCA(15,2)=1.0308CCA(16,2)=1.030
C      CCA(17,2)=1.0308CCA(18,2)=1.0308CCA(19,2)=1.0318CCA(20,2)=1.031
C      CCA(21,2)=1.0318CCA(22,2)=1.031
30     CCA(01,3)=1.0008CCA(02,3)=0.9148CCA(03,3)=0.8058CCA(04,3)=0.745
C      CCA(05,3)=0.6998CCA(06,3)=0.5948CCA(07,3)=0.6378CCA(08,3)=0.670
C      CCA(09,3)=0.7338CCA(10,3)=0.7838CCA(11,3)=0.8318CCA(12,3)=0.868
C      CCA(13,3)=0.8988CCA(14,3)=0.9388CCA(15,3)=0.9388CCA(16,3)=0.938
35     CCA(17,3)=0.9388CCA(18,3)=0.9388CCA(19,3)=0.9388CCA(20,3)=0.938
C      CCA(21,3)=0.9388CCA(22,3)=0.938
C      CCA(01,4)=1.0008CCA(02,4)=0.7198CCA(03,4)=0.6008CCA(04,4)=0.626
C      CCA(05,4)=0.5078CCA(06,4)=0.5508CCA(07,4)=0.5168CCA(08,4)=0.534
C      CCA(09,4)=0.5758CCA(10,4)=0.6108CCA(11,4)=0.6448CCA(12,4)=0.676
40     CCA(13,4)=0.7058CCA(14,4)=0.7598CCA(15,4)=0.8048CCA(16,4)=0.844
C      CCA(17,4)=0.8798CCA(18,4)=0.8808CCA(19,4)=0.8818CCA(20,4)=0.883
C      CCA(21,4)=0.8848CCA(22,4)=0.885
C      CCA(01,5)=1.0008CCA(02,5)=0.6538CCA(03,5)=0.6328CCA(04,5)=0.582
C      CCA(05,5)=0.5458CCA(06,5)=0.5108CCA(07,5)=0.4708CCA(08,5)=0.490
45     CCA(09,5)=0.5328CCA(10,5)=0.5598CCA(11,5)=0.5868CCA(12,5)=0.614
C      CCA(13,5)=0.6398CCA(14,5)=0.6838CCA(15,5)=0.7198CCA(16,5)=0.747
C      CCA(17,5)=0.7698CCA(18,5)=0.7978CCA(19,5)=0.8358CCA(20,5)=0.838
C      CCA(21,5)=0.8418CCA(22,5)=0.844
C      DO 1 I=1,5
C      NPTAT(I)=NPTAC(I)
50     1 TCI(I)=CCI(I)
C      DO 3 I=1,22
C      CNA(I,1)=CNA(I,1)*0.001
C      TNA(I,1)=CNA(I,1)
C      CCA(I,1)=S(STRESS,STRAIN,NPTS,CNA(I,1))
55     3 TCA(I,1)=S(STRT,STNT,NPTS,TNA(I,1))
C      DO 2 I=1,22
C      DO 2 J=2,5
HSSPT 2
HSSPT 3
HSSPT 4
HSSPT 5
HSSPT 6
HSSPT 7
HSSPT 8
HSSPT 9
HSSPT 10
HSSPT 11
HSSPT 12
HSSPT 13
HSSPT 14
HSSPT 15
HSSPT 16
HSSPT 17
HSSPT 18
HSSPT 19
HSSPT 20
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HSSPT 51
HSSPT 52
HSSPT 53
HSSPT 54
HSSPT 55
HSSPT 56
HSSPT 57
HSSPT 58

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SUBROUTINE HSSPT 74/74 OPT=0 ROUND=0/ TRACE

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	TNA(I,J)=TNA(I,1)	HSSPT	59
	CNA(I,J)=CNA(I,1)	HSSPT	60
60	TCA(I,J)=CCA(I,J)*TCA(I,1)	HSSPT	61
2	CCA(I,J)=CCA(I,J)*CCA(I,1)	HSSPT	62
	IF(IDEBUGR.GE.8) RETURN	HSSPT	63
	WRITE(6,11) (CCI(I),I=1,5)	HSSPT	64
	WRITE(6,12) ((CCA(I,J),CNA(I,J),J=1,5),I=1,22)	HSSPT	65
65	WRITE(6,13) (TCI(I),I=1,5)	HSSPT	66
	WRITE(6,12) ((TCA(I,J),TNA(I,J),J=1,5),I=1,22)	HSSPT	67
	RETURN	HSSPT	68
	END	HSSPT	69

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