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FRACTURE MECHANICS ANALYSIS OF SINGLE AND DOUBLE ROWS OF FASTENER HOLES LOADED IN BEARING

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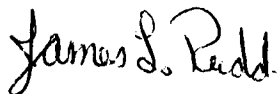
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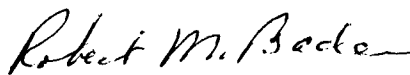
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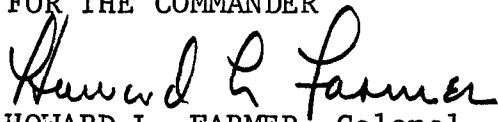


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output conventions, execution times, and limitations are discussed. Results of some example analyses are presented.

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FOREWORD

The developments documented in this report were carried out at the Aeroelastic and Structures Research Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, under Contract No. F33615-74-C-3063 (Project 1367, Task 136703) from the U.S. Air Force Flight Dynamics Laboratory. Mr. James L. Rudd (AFFDL/FBE) served as technical monitor. The authors gratefully acknowledge the many contributions by Mrs. Susan French of the Aeroelastic and Structures Research Laboratory. Mrs. French was involved with the detailed programming aspects of the work throughout the entire project. This report is the third in a series, covering research conducted during February-April 1975, and was submitted for technical review in May 1975. The other reports in the series are AFFDL-TR-75-51 (Fracture Mechanics Analysis of an Attachment Lug), AFFDL-TR-75-70 (Fracture Mechanics Analysis of Centered and Offset Fastener Holes in Stiffened and Unstiffened Panels Under Uniform Tension), and AFFDL-TR-76-12 (Numerical Computation of Stress Intensity Factors for Aircraft Structural Details by the Finite Element Method). The contractor's report number is ASRL TR 177-3.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1 INTRODUCTION.....	1
2 SROW AND DROW PROGRAMS.....	3
2.1 Model and Input Conventions for Program SROW....	3
2.2 Model and Input Conventions for Program DROW....	6
2.3 Required Subprograms and Other Features.....	9
2.4 Model Generation and Program Flow.....	10
2.4.1 Procedure SBL.....	11
2.4.2 Procedure DBL.....	12
2.4.3 Executive Flow.....	12
2.5 Output Conventions and Error Messages.....	13
2.6 Status of Programs.....	14
3 DEMONSTRATION EXAMPLES.....	15
4 DISCUSSION AND CONCLUSIONS.....	17
APPENDICES	36
A Program SROW and Procedure SBL	36
B Program DROW and Procedure DBL	51

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Structure Modeled by Program SROW	21
2	Input Conventions for Program SROW	22
3	Structure Modeled by Program DROW	23
4	Input Conventions for Program DROW	24
5	Substructure Hierarchy (Procedure SBL)	25
6	Substructure Hierarchy (Procedure DBL)	26
7	Executive Flow (Program SROW or Program DROW)	27
8	Sample Output (Program DROW)	28
9	Example of Panel with One Row of Three Fastener Holes .	29
10	Butterfly Plot (Center Hole Damaged)	30
11	Butterfly Plot (Right Hole Damaged)	31
12	Example of Panel with Two Rows of Three Fastener Holes	32
13	Butterfly Plot (Center Hole in Upper Row Damaged) . . .	33
14	Butterfly Plot (Center Hole in Lower Row Damaged) . . .	34
15	Definition of Crack Parameters for Classical Solutions	35

Section 1

INTRODUCTION

This is the third of a series of reports on the development of finite-element analysis procedures for computation of linear elastic stress intensity factors associated with cracks in common aircraft structural details. The first report in the series [1] reviewed the foundations of the assumed-stress hybrid finite-element method and its application to the formulation of a special element which contains a crack-tip singularity, but which is also compatible with conventional assumed-displacement elements along its boundaries. The second report [2] documented some additions to the ASRL FEABL-2 software for substructure analysis, the development of a new hybrid element to connect the vicinity of a fastener hole to a cartesian panel geometry, and the program codes for several pieces of substructure which were put together to model a tension panel with a single fastener hole. Performance tests which were conducted on the new hybrid element demonstrated, among other things, that the element could function accurately at a fastener hole subjected to a cosine bearing pressure distribution applied either directly to the hybrid element or to the inner boundary of some rings of quadrilateral elements inserted between the hybrid element and the fastener hole surface. In the present report, the pieces and parts are shuffled and presto!--two new finite-element models appear. They are tension panels with either a single row of fastener holes, or a double row of holes on staggered centerlines. A new procedure

is introduced for each model: SBL and DBL, which generate the far-field substructures. However, the new procedures are executives which merely use the previously developed basic substructures to create different design details and different loading. The fastener hole rows are now located along the top edge of the panel, and tension is introduced by a cosine bearing pressure distribution at each hole.

Section 2

SROW AND DROW PROGRAMS

Parametric codes designated SROW and DROW have been developed to generate and analyze the single- and double-fastener-row panels. Programs SROW and DROW are executive controllers which direct procedures SBL and DBL, respectively, as well as other previously developed procedures.

2.1 Model and Input Conventions for Program SROW

Fig. 1 illustrates the structure which is modeled by program SROW: a skin panel with a horizontal row of equally spaced fastener holes near the top edge. The centerline of the row is placed below the edge by half the center-to-center spacing of the fasteners. The panel may have up to 10 holes. The bottom edge of the panel is restrained. Load is introduced by fastener bearing forces applied at the holes. These forces are represented by cosine pressure distributions. The bearing forces may be different for different fastener holes. The model assumes that one fastener hole is damaged. The user specifies the location of the damaged hole, whether it has a single crack or two cracks 180 degrees apart, and the range of angular crack positions to be analyzed.

Fig. 2 summarizes the input data card conventions. Five or six input data cards are required to supply the following information:

1. Panel Parameters

NHOLES = Number of fastener holes in panel

CLSPC = Center-to-center hole spacing

RI = Hole radius
IDMGD = Position of the damaged hole
LENGTH = Total length of the panel
THK = Panel thickness

2. Load Parameters

BFORCE_i = Total bearing force to be applied to the
 ith hole in the row

(Note: these data are continued on a second card
for panels with NHOLES > 8.)

3. Crack Parameters

A(1) = Length of first crack
A(2) = Length of second crack
IPOS(1) = Initial position number of first crack
IPOS(2) = Final position number of first crack

4. Material Properties

E = Young's modulus
ν = Poisson's ratio

5. Print Control Parameters

KT1 = Control for optional FEABL-2 output
KT2 = Control for procedure SBL output
KT3 = Control for procedure RING output

Any value from 1 to 10 may be chosen for NHOLES. The fastener hole radius is restricted to: $CLSPC/12 \leq RI \leq CLSPC/8$. The fastener holes are considered to be in the sequence 1,2,..., NHOLES from

left to right. The damaged hole is defined by its sequence number:

$$1 \leq \text{IDMGD} \leq \text{NHOLES} \quad (1)$$

The panel width is computed internally as $\text{NHOLES} * \text{CLSPC}$ by program SROW.

Bearing forces for each fastener hole are specified individually on the second data card, with a continuation card required if the panel has 9 or 10 holes. The bearing force values may be zero or positive. Negative values (i.e., compressive load transfer) can be processed by the program, but will be incorrectly applied as a distributed tension on the upper half of the hole rather than as a bearing pressure on the lower half. Therefore, the use of negative bearing forces is not recommended for the present version of program SROW. The bearing forces are converted internally to consistent nodal forces which model a cosine pressure distribution statically equivalent to the bearing force.

Input parameters $A(1)$, $A(2)$ are the actual crack lengths, as measured from the edge of the fastener hole to the crack tip. The cracks are placed so as to emanate radially from the fastener hole. If a case with only one crack is to be analyzed, specify $A(2) = 0.0$. Crack lengths in the range:

$$0 \leq A(1), A(2) \leq 1.27(RI) \quad (2)$$

are permitted. The initial and final angular positions of the first crack are controlled by the crack position numbers, in accordance with:

$$\begin{aligned} \theta_{\text{initial}} &= (\text{IPOS}(1)-1)\Delta\theta \\ \theta_{\text{final}} &= (\text{IPOS}(2)-1)\Delta\theta \\ \Delta\theta &= \pi/12 \text{ rad.} = 15 \text{ deg.} \end{aligned} \quad (3)$$

If a second crack exists, it is always positioned 180 degrees from the first crack. Permissible values of the position numbers are:

$$\begin{aligned} 1 &\leq \text{IPOS}(1) \leq n_{\max} \\ \text{IPOS}(1) &\leq \text{IPOS}(2) \leq n_{\max} \end{aligned} \quad (4)$$

where

$$\begin{aligned} n_{\max} &= 12 \text{ if } A(2) \neq 0.0 \\ n_{\max} &= 24 \text{ if } A(2) = 0.0 \end{aligned}$$

Solutions are executed automatically for the angular positions from θ_{initial} to θ_{final} in 15-degree increments. A single solution is executed if $\text{IPOS}(2) = \text{IPOS}(1)$.

The print control parameters may be used to delete nonessential output by setting:

K*Ti* = FORTRAN unit number for line
printer at user's computing
facility.

The FORTRAN unit number is the value specified for the line printer in a FORTRAN-IV print instruction; e.g.:

WRITE (6,1000) A, B, C

(Unit number = 6)

Any other values for K*Ti* (*i* = 1,2,3) will permit the nonessential output to be printed. Full output is recommended for the initial trial run when program SROW is first imported to a computing facility. Deletion of all three options is recommended for production runs.

2.2 Model and Input Conventions for Program DROW

Fig. 3 illustrates the structure which is modeled by program DROW: a skin panel with two horizontal rows of equally spaced

fastener holes near the top edge. The upper and lower rows are designated row 1 and row 2, respectively. The centerline of row 1 is placed below the top edge by half the fastener center-to-center spacing. Row 2 is staggered to the right of row 1 by half the center-to-center spacing. The panel may have up to 8 fastener holes per row. The bottom edge of the panel is restrained. Load is introduced by fastener bearing forces applied at the holes. These forces are represented by cosine bearing pressure distributions. A different bearing force may be specified for each hole. The model assumes that one fastener hole is damaged. The user specifies the location of the damaged hole, whether it has a single crack or two cracks 180 degrees apart, and the range of angular crack positions to be analyzed.

Fig. 4 summarizes the input data card conventions. Six input data cards are required to supply the following information:

1. Panel Parameters

NHOLES = Total number of holes per row
 CLSPC = Center-to-center fastener spacing
 RI = Hole radius
 IROW = Row which contains damaged hole
 IDMGD = Position of damaged hole within row
 LENGTH = Total length of panel
 THK = Panel thickness

2. Load Parameters (Row 1)

BFORCE_i = Total bearing force to be applied
 to the *i*th hole in the row

3. Load Parameters (Row 2)

BFORCE_i = Total bearing force to be applied
to the ith hole in the row

4. Crack Parameters

A(1) = Length of first crack

A(2) = Length of second crack

IPOS(1) = Initial position number of first crack

IPOS(2) = Final position number of first crack

5. Material Properties

E = Young's modulus

v = Poisson's ratio

6. Print Control Parameters

KT1 = Control for optional FEABL-2 output

KT2 = Control for procedure DBL output

KT3 = Control for procedure RING output

Any value from 1 to 8 may be chosen for NHOLES. The fastener hole radius is restricted to:

$$CLSPC/12 \leq RI \leq CLSPC/8 \quad (5)$$

The fastener holes are considered to be in the sequence 1,2,..., NHOLES from left to right in each row. The location of the damaged hole is specified by row number IROW = 1 or 2 and position number within the row (Eq. 1). The panel width is computed internally by program DROW as CLSPC * (NHOLES + 0.5).

Bearing forces for each fastener hole are specified individually on the second data card for row 1 and on the third data card for

row 2. The bearing force values may be zero or positive. Negative values (i.e., compressive load transfer) can be processed by the program, but will be incorrectly applied as a distributed tension on the upper half of the hole rather than as a bearing pressure on the lower half. Therefore, the use of negative bearing forces is not recommended for the present version of program DROW. The bearing forces are converted internally to consistent nodal forces which model a cosine pressure distribution statically equivalent to the bearing force.

The crack parameters and print control parameters are defined in the same manner and subject to the same restrictions as for program SROW. See the latter part of Subsection 2.1 for details.

2.3 Required Subprograms and Other Features

Programs SROW and DROW require the following subprograms for execution:

1. ASRL FEABL-2 subroutines ASMLTV, ASMSUB, BCON, FACT, ORK, QBACK, SETUP, SIMULQ, STACON, and XTRACT.
2. IBM Scientific Subroutine Package subroutines MFSD and SINV.
3. ASRL elements PCRK59 and QUAD4.
4. Procedures HOLEL, LUG, and RING, together with their associated subroutines.
5. Procedure SBL (for program SROW) or procedure DBL (for program DROW).

No external (disk or tape) files are required by either program.

The core memory requirements are as follows:

<u>Program SROW</u>	<u>Program DROW</u>	
272	344	KBYTES
68,000 ₁₀	86,000 ₁₀	Decimal Words
204,640 ₈	247,760 ₈	Octal Words

Execution times range from 0.25 to 1.5 CPU minutes, depending upon the range of crack parameters investigated. The above statistics are based on program code generated by IBM FORTRAN-G1 and FORTRAN-H compilers, with demonstration runs made on an IBM 370/168 computer.

Programs SROW and DROW are supplied ready to execute on systems with IBM-standard FORTRAN unit members for the card reader (unit 5) and line printer (unit 6). The programs may be modified for other systems simply by changing the statements:

```
      .  
      .  
      .  
      KR = 5  
      KW = 6  
      .  
      .  
      .
```

to the proper unit numbers. These statements appear near the beginning of the SROW and DROW MAIN programs.

2.4 Model Generation and Program Flow

The panel finite-element models are subdivided into two major components: the immediate neighborhood of the damaged fastener hole and the remainder of the structure. The region near the damaged hole is generated by procedure RING as an annulus substructure with boundary nodes on its inner and outer circumferences. The remainder of the structure is generated by procedure SBL or procedure DBL and statically condensed for coupling to the outer circumference of the ring.

2.4.1 Procedure SBL

Fig. 5 illustrates the hierarchy and numbering convention for the substructure generated by procedure SBL. Procedure HOLEL is used to generate the region around each fastener hole. Two calls to HOLEL are required: one for the undamaged holes for which the inner boundary of HOLEL is set at $R_0 = RI$, and one for the damaged hole for which $R_0 = 2.52 (RI)$ to accommodate the ring. The undamaged HOLEL is assembled repeatedly. Procedure LUG is used to generate the lower portion of the panel.

The following node numbering scheme has been adopted to facilitate automatic generation of the substructure interconnections while satisfying the requirement that the boundary nodes be numbered last to permit static condensation:

1. The HOLEL inner boundaries are numbered first, in the left-to-right sequence corresponding to the hole position. Thus, nodes 1 to 24 are placed in the first HOLEL, nodes 25 to 48 in the second, etc.
2. The mid-edge nodes on the fastener row centerline, the fastener row upper edge nodes, and the fastener row lower edge* nodes are numbered in order, from right to left. Fictitious nodes are included at the hole centers to facilitate the numbering algorithm. These are later restrained without having received any stiffnesses during the assembly.
3. Finally, 24 additional node numbers are assigned to the inner boundary of the damaged HOLEL, and the original node numbers are reassigned to the lower edge of the LUG substructure. Some of the latter will be left over, and are, therefore, restrained without receiving stiffnesses.

The node numbers shown in Fig. 5 are the final assignments for a case in which the third in a row of three fastener holes is damaged.

* The lower edge node numbers are also assigned to the upper edge of the LUG substructure.

The various substructures are now assembled and the fictitious nodes are restrained. The bottom edge of the panel is also restrained and nodal forces representing the bearing loads are applied at the undamaged holes, as indicated in Fig. 5. Finally, the assembled substructure is statically condensed to a "Cheshire Cat" (nothing left but the smile), consisting of the 24 nodes on the damaged HOLEL inner boundary, ready for final assembly.

2.4.2 Procedure DBL

Fig. 6 illustrates the hierarchy and numbering convention for the substructure generated by procedure DBL. The model creation is generally similar to what has just been described, the only significant differences being some details of the node numbering pattern and the inclusion of QUAD4 elements in the assembly to account for the stagger between the two fastener rows. The end product of procedure DBL is another Cheshire Cat, ready for final assembly.

2.4.3 Executive Flow

Programs SROW and DROW have the same executive flow, summarized in Fig. 7. The input data are read and printed for reference, and procedure SBL or procedure DBL is called to create the appropriate Cheshire Cat. The Cheshire Cat is designated as substructure 1 for the final assembly. At this point, the process of setting up the final substructure is started. A re-entry point appears in the midst of the interconnection generation algorithm (statement 205 in either program) to permit the band-margin computation sub-routine (ORK) to erase the $\tilde{K}$ and $\tilde{q}$ data from the previous analysis.

The Cheshire Cat is now assembled, and procedure RING is used to generate the cracked ring (substructure 2), which is also assembled. Nodal forces for the bearing load on the damaged hole are now applied, and a global displacement solution is obtained for the structure. Finally, a back-substitution solution is executed for the cracked ring, displacements q_L are extracted for one or two PCRK59 elements, and NASA/ASTM-standard stress intensity factors K_I and K_{II} are computed. Logical IF statements at the end of the loop determine whether the angular crack position is to be incremented for another analysis. If another case remains to be analyzed, the crack angle is incremented and the program branches back to the re-entry point at statement 205.

2.5 Output Conventions and Error Messages

Fig. 8 illustrates a sample output from program DROW with all optional printout deleted. The heading identifies the program which was executed and repeats the user's input data for checking. Below the heading appears a table giving the angular position, K_I and K_{II} for each crack. If the input data have been given in units of lbs. for bearing force, psi for Young's modulus and inches for dimensions, K_I and K_{II} are in units of $\text{psi } \sqrt{\text{in.}}$. The crack angles are given in degrees. The output from program SROW is similar.

Error messages printed by procedure RING and by the FEABL-2 software have been documented elsewhere [2,3]. In addition, procedures SBL and DBL print error messages and terminate execution if the restriction given by Eq. 5 is violated. Finally, programs SROW and DROW print warning messages, change the panel length, and

continue execution if the user has input a length too short compared to the center-to-center spacing of the fasteners. The programs are always executed with:

$$\begin{aligned} \text{LENGTH} &\geq 2 \text{ (CLSPC) for program SROW} \\ \text{LENGTH} &\geq 3 \text{ (CLSPC) for program DROW} \end{aligned} \quad (6)$$

2.6 Status of Programs

Programs SROW and DROW are maintained as 029-punched FORTRAN-IV source decks, sequenced by individual subroutine. All input options described in subsections 2.1 and 2.2 have been exercised successfully for panels containing up to three fastener holes per row. Source listings appear in Appendix A for program SROW and procedure SBL, and in Appendix B for program DROW and procedure DBL. Listings for the other procedures appear in a previous report in this series [2].

Section 3

DEMONSTRATION EXAMPLES

Figure 9 illustrates an example of a single row of three fastener holes, each loaded by a 1,000-lb. bearing force in a 1-inch thick panel. Sample analyses of this structure were run with the center and right holes damaged by a single crack. Butterfly plots for K_I and K_{II} are presented in Fig. 10 (center hole damaged) and Fig. 11 (right hole damaged). The observed behavior is similar to solutions for cosine bearing loading applied to an attachment lug detail [1]. In particular, maxima for K_I are seen to occur for cracks at ± 105 degrees from the line of action of the applied load ($\theta = 195$ and 345 degrees), in the symmetric case (Fig. 10), and significant K_I values occur for cracks on the load line ($\theta = 0$ degrees) due to the local hoop tension effect of the bearing pressure. Asymmetric behavior is evident for both K_I and K_{II} in the case of the right hole damaged (Fig. 11). A curious result for this case is that the maximum K_I occurs when the crack is positioned away from the neighboring fastener hole ($\theta = 345$ degrees).

Figure 12 illustrates an example problem for a similar structure with two rows of fasteners. The results of two example analyses of this structure are plotted in Figs. 13 and 14. In Fig. 13, the center hole in the upper row is damaged. These results are comparable to the behavior of the single-row cases, except that asymmetry is now introduced by the presence of the second row of fasteners. Also, the maxima of K_I now shift downward toward the second fastener row. In Fig. 14, the center hole in the lower row is damaged. Comparison with Fig. 13 shows that K_I and K_{II} have increased roughly by a factor

of 2, an effect which may be attributed to the fact that the damaged hole is located deeper in the load-transfer zone of the structure. Solution asymmetry is very slight for this case.

Section 4

DISCUSSION AND CONCLUSIONS

Unfortunately, there exist no independent K_I solutions for cracks at fastener holes loaded in bearing. However, some approximate correlations can be made by comparison with solutions available for similar problems, if the bearing forces are translated into average tension for the nominal cross section of the panel. The conversions are given by:

$$\begin{aligned}\sigma_1 &\approx 3 \times 1,000 \text{ lb./30 in}^2 = 100 \text{ psi} \\ \sigma_2 &\approx 6 \times 1,000 \text{ lb./35 in}^2 = 171.5 \text{ psi}\end{aligned}\tag{7}$$

for the single- and double-row cases, respectively. Thus, one might logically expect to find, e.g.,:

$$K_I \text{ (Fig. 14)} / K_I \text{ (Fig. 10)} = 1.715\tag{8}$$

for a given crack angle, together with a similar result for K_{II} .

The following summary of calculations tends to confirm the expected behavior:

<u>Item</u>	<u>From Fig. 10</u>	<u>From Fig. 14</u>	<u>Ratio</u>	<u>% Error</u>
K_I at $\theta = 0^\circ$	250 psi $\sqrt{\text{in}}$	431 psi $\sqrt{\text{in}}$	1.72	0.3
K_I at $\theta = 180^\circ$	250	436	1.74	1.5
K_{II} at $\theta = 210^\circ$	181	324	1.79	4.4
K_{II} at $\theta = 330^\circ$	181	320	1.77	3.2

An approximate comparison may also be made with published solutions for cracks in an infinite plate under uniform tension [4]:

$$K_I(\theta=0^\circ) = \frac{\sigma\sqrt{4b} \sin(\frac{\pi C}{2b})}{\sqrt{\sin(\frac{\pi C}{b})}}\tag{9}$$

for a row of repeated cracks, or:

$$K_I (\theta=0^\circ) = \sigma \sqrt{\pi a} F (a, R_I) \quad (10)$$

for a single crack emanating from a single hole. The quantities a, b, c, R_I are defined in Fig. 15. For the present case, the results of the comparison are as follows:

<u>Program</u>	<u>Computed K_I</u>	<u>K_I (Eq. 9)</u>	<u>K_I (Eq. 10)</u>
SROW (Fig. 10)	250	246	271
DROW (Fig. 14)	431-436	421	465

where the stresses σ_1, σ_2 given by Eqs. 7 have been used in Eq. 9 and Eq. 10. The fact that the computed K_I values are below the classical solution for a crack at a hole may be attributed to incomplete development of the nominal tension in the immediate vicinity of the fastener bearing load. Also, it is comforting to note that the finite-element results are bounded by the two classical solutions, within a range of about 10 percent.

The results presented in this report demonstrate that the assumed-stress hybrid finite element method is capable of providing stress intensity factor solutions for a wide variety of structural details. The specific program codes documented in this report treat panels loaded by bearing through a single row or a double staggered row of fastener holes near one edge of the panel. The programs are presently restricted to fairly widely spaced fasteners, in order to remain in the parameter ranges for which the most accurate performance of the individual finite elements was demonstrated in earlier work.

This restriction and an approximate comparison of the computed results with classical solutions indicate that the finite-element computations for K_I and K_{II} are within 5 to 10 percent of the exact answers. A better error assessment does not seem likely in the near future because of the difficulty in obtaining classical solutions for the very complicated geometry and loading associated with these structural details. Only a few demonstration examples have been presented, but the possibilities for these programs are legion. Situations in which the bearing load varies from one fastener to another may be of interest to the detail designer. One extremely interesting example is the question of stress intensity at a hole which has cracked sufficiently to unload its fastener. Will this result in crack arrest, or will the bearing loads from nearby fasteners still impose a K_I great enough to continue crack growth or to cause fracture? This and other example solutions will be presented in the final report in this series.

REFERENCES

1. Orringer, O., "Fracture Mechanics Analysis of an Attachment Lug", Aeroelastic and Structures Research Laboratory, MIT, ASRL TR 177-1, AFFDL-TR-75-51, December 1974.
2. Stalk, G. and Orringer, O., "Fracture Mechanics Analysis of Centered and Offset Fastener Holes in Stiffened and Unstiffened Panels under Uniform Tension", Aeroelastic and Structures Research Laboratory, MIT, ASRL TR 177-2, AFFDL-TR-75-70, April 1975.
3. Orringer, O. and French, S. E., "FEABL (Finite Element Analysis Basic Library) User's Guide", Aeroelastic and Structures Research Laboratory, MIT, ASRL TR 162-3, AFOSR-TR-72-2228, August 1972. (Supplemented by ASRL TM 162-3-3 and ASRL TM 162-3-4, February 1974.)
4. Paris, P. C. and Sih, G. C., "Stress Analysis of Cracks", ASTM STP 381, Fracture Toughness Testing and Its Applications, 1965, pp. 30-83.

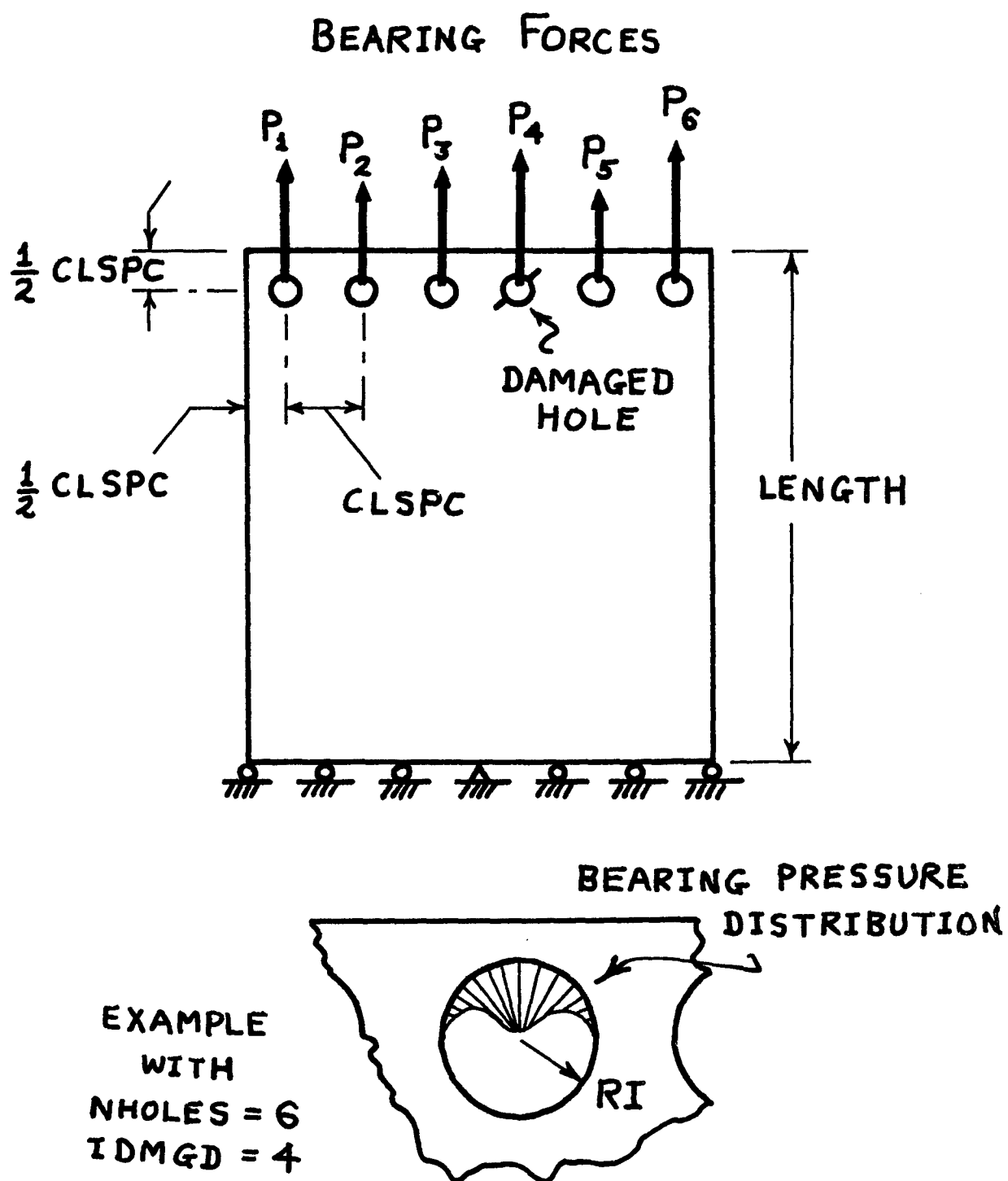
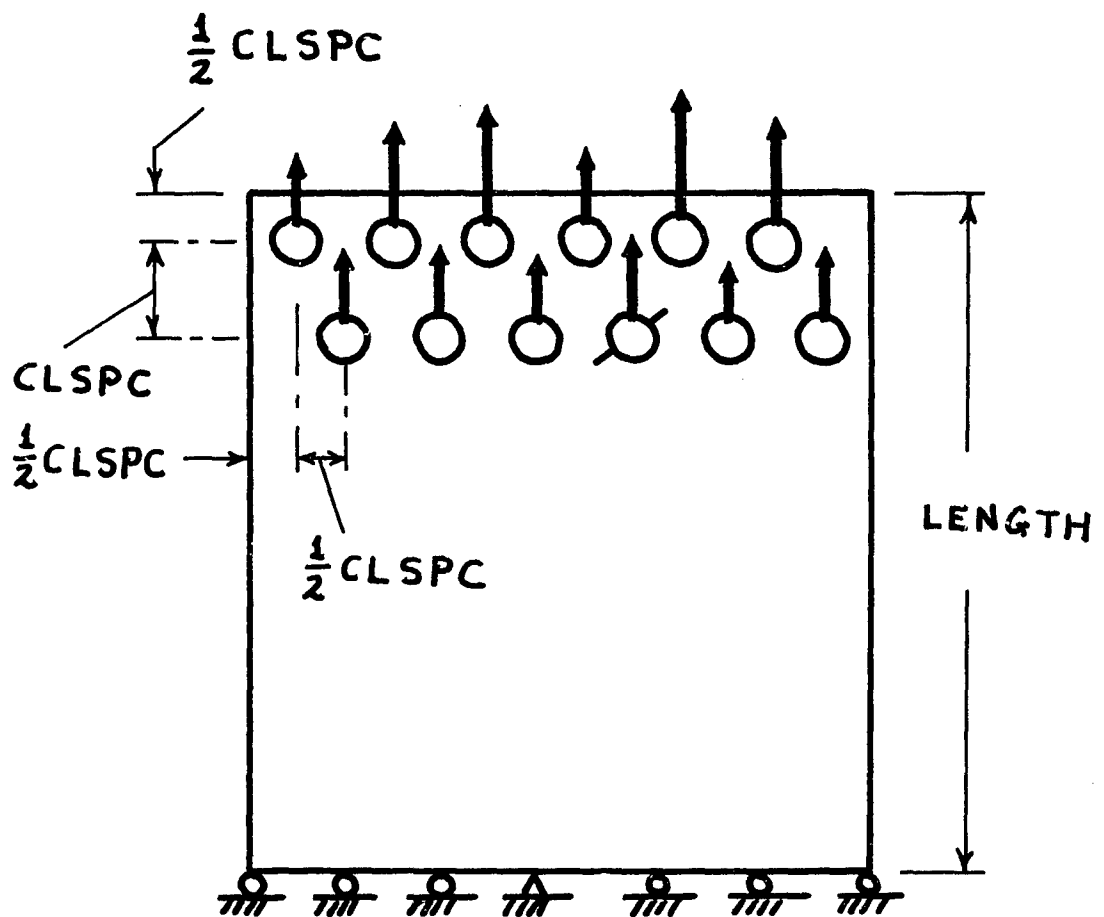


FIG. 1 STRUCTURE MODELED BY PROGRAM SROW

JOB TITLE		PROGRAMMER		DATE		ENGINEER		SHEET		OF																																																																						
PROGRAM SROW - INPUT DATA CONVENTIONS		FRENCH		1 APRIL 1975		STALK/DORRINGER		1		1																																																																						
JOB NO.	81739																																																																															
CARD #	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	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	NHOLE1 ← CLSPAC → RI → IDMGD ← LENGTH → THK → (I5, 2E10.3, I5, 2E10.3)																																																																															
2	← BFORCE1 → BFORCE2 → BFORCE3 → BFORCE4 → BFORCE5 → BFORCE6 → BFORCE7 → BFORCE8 → (8E10.3) ← BFORCE9 → BFORCE10 → (2E10.3)																																																																															
2 (cont)	Continuation card, if req'd.																																																																															
3	← A(1) → A(2) → IPDS(1) IPDS(2) (2E10.3, 2I5)																																																																															
4	← E → (2E10.3)																																																																															
5	*KT1 *KT2 *KT3 → (3I5)																																																																															

FIG. 2 INPUT CONVENTIONS FOR PROGRAM SROW



EXAMPLE
WITH
NHOLES = 6
IROW = 2
IDMGD = 4

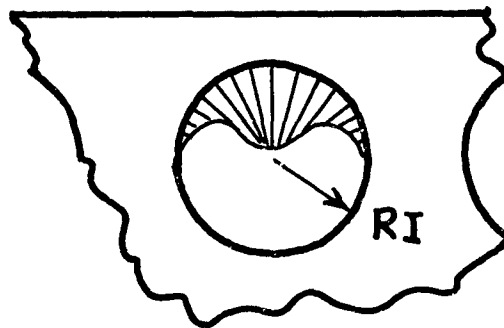


FIG. 3 STRUCTURE MODELED BY PROGRAM DROW

JOB TITLE		PROGRAM		DROW - INPUT DATA CONVENTIONS		ENGINEER		STALK/ORRINGER	
JOB NO.		81739		FRENCH		DATE		1 APRIL 1975	
PROGRAMMER		FRENCH		SHEET		1		OF	
CARD #		1		2		3		4	
1	WHOLE5 ← CLSPC →	← RI →	→ IROW 10M6D ←	← LENGTH →	← THK →				
	(15, 2E10.3, 15, 2E10.3)								
2	← BFORCE ₁ →	← BFORCE ₂ →	← BFORCE ₃ →	← BFORCE ₄ →	← BFORCE ₅ →	← BFORCE ₆ →	← BFORCE ₇ →	← BFORCE ₈ →	
	(8E10.3) Bearing loads for row #1								
3	← BFORCE ₁ →	← BFORCE ₂ →	← BFORCE ₃ →	← BFORCE ₄ →	← BFORCE ₅ →	← BFORCE ₆ →	← BFORCE ₇ →	← BFORCE ₈ →	
	(8E10.3) Bearing loads for row #2								
4	← A(1) →	← A(2) →	→ 2POS(1) 1POS(2) →						
	(2E10.3, 2I5)								
5	← E →	← V →							
	(2E10.3)								
6	← KTI →	← KTR →	← KTS →						
	(3I5)								

FIG. 4 INPUT CONVENTIONS FOR PROGRAM DROW

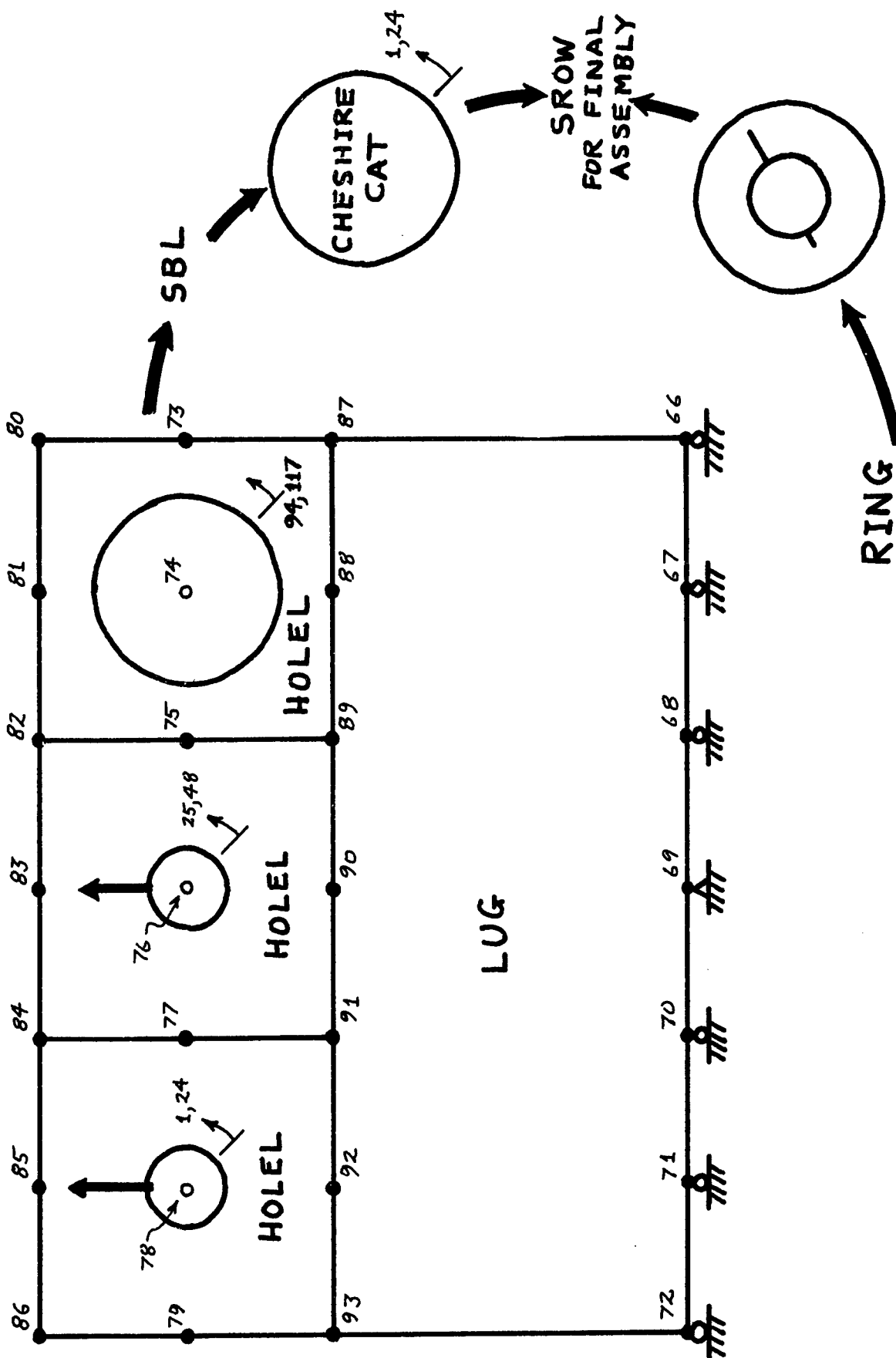


FIG. 5 SUBSTRUCTURE HIERARCHY (PROCEDURE SBL)

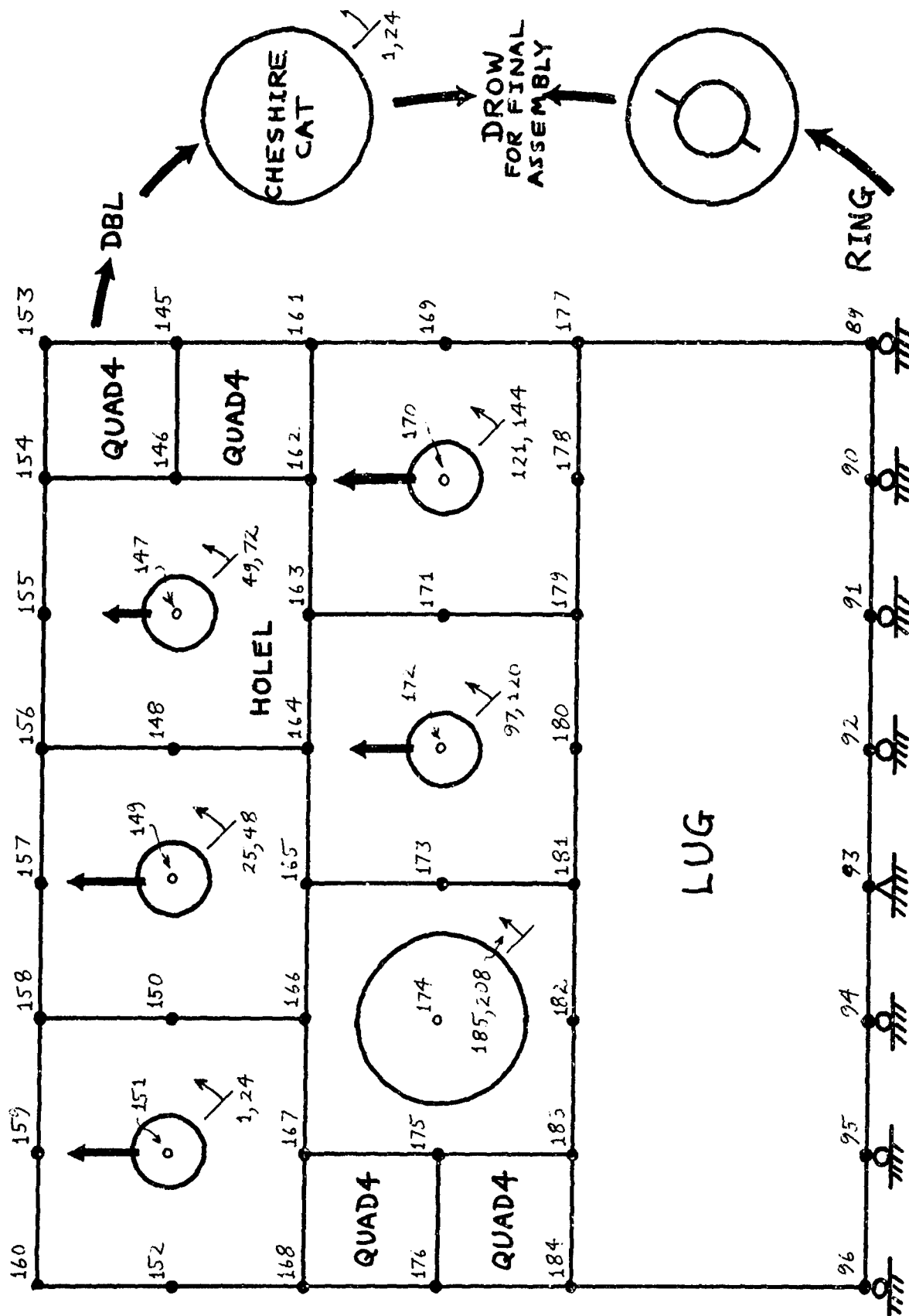


FIG. 6 SUBSTRUCTURE HIERARCHY (PROCEDURE DBL)

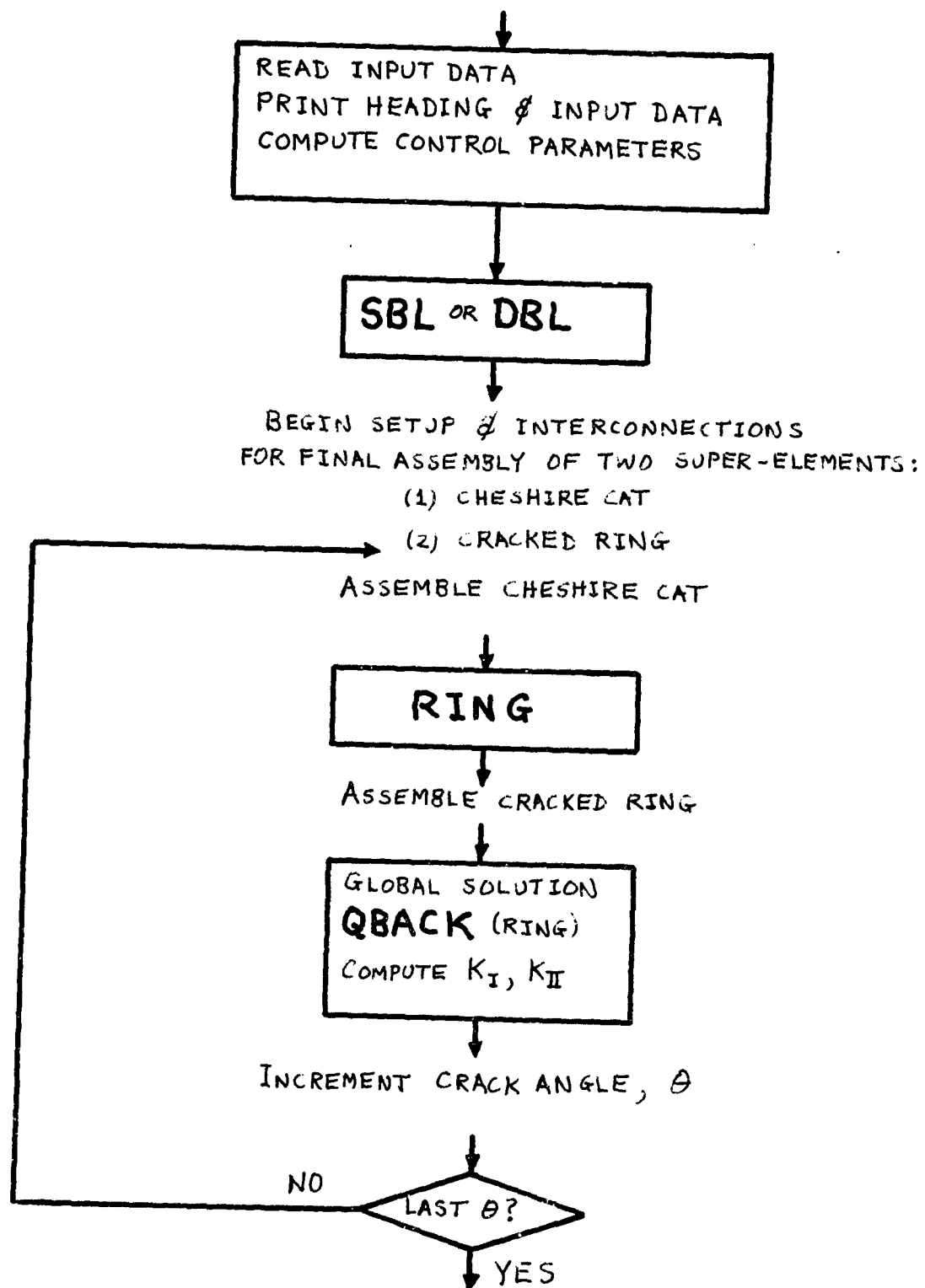


FIG. 7 EXECUTIVE FLOW (PROGRAM SROW OR PROGRAM DROW)

DOUBLE HOLT LINE

PROBLEM NO. 6

INPUT DATA

NUMBER OF HOLES PER ROW= 3
 CENTER LINE SPACING OF HOLES= 0.10000E+02
 BEARING HOLE RADIUS= 0.12500E+01
 DAMAGED HOLE IN ROW 2 IS 2 FROM L.H.S.
 PLATE LENGTH= 0.30000E+02
 PLATE WIDTH= 0.35000E+02
 PLATE THICKNESS= 0.10000E+01
 BEARING LOADS : HOLE FORCE (LBS)

ROW= 1	1	0.10000E+04
ROW= 1	2	0.10000E+04
ROW= 1	3	0.10000E+04
ROW= 2	1	0.10000E+04
ROW= 2	2	0.10000E+04
ROW= 2	3	0.10000E+04

CRACK DATA:

TOTAL NUMBER OF CRACKS= 1
 CRACK NO. CRACK LENGTH

1	0.12500E+01
---	-------------

INITIAL CRACK POSITION= 0.0 PIVAL CRACK POSITION= 345.000 (+180 DEGREES FOR CRACK NO. 2 POSITION)

MATERIAL PARAMETERS:

YOUNGS MODULUS (E)= 0.10000E+08
 POISSONS RATIO= 0.300

CRACK NO. 1	ANGLE= 0.0	KI= 0.43142E+03	KII= 0.31922E+02
-------------	------------	-----------------	------------------

CRACK NO. 1	ANGLE= 15.000	KI= 0.42213E+03	KII= 0.15192E+03
-------------	---------------	-----------------	------------------

CRACK NO. 1	ANGLE= 30.000	KI= 0.39588E+03	KII= 0.27688E+03
-------------	---------------	-----------------	------------------

CRACK NO. 1	ANGLE= 45.000	KI= 0.30798E+03	KII= 0.25876E+03
-------------	---------------	-----------------	------------------

CRACK NO. 1	ANGLE= 60.000	KI= 0.20125E+03	KII= 0.19908E+03
-------------	---------------	-----------------	------------------

CRACK NO. 1	ANGLE= 75.000	KI= 0.11763E+03	KII= 0.10212E+03
-------------	---------------	-----------------	------------------

CRACK NO. 1	ANGLE= 90.000	KI= 0.88530E+02	KII= 0.63011E+01
-------------	---------------	-----------------	------------------

CRACK NO. 1	ANGLE= 105.000	KI= 0.10430E+03	KII= 0.92770E+02
-------------	----------------	-----------------	------------------

CRACK NO. 1	ANGLE= 120.000	KI= 0.18474E+03	KII= 0.19004E+03
-------------	----------------	-----------------	------------------

CRACK NO. 1	ANGLE= 135.000	KI= 0.29877E+03	KII= 0.26816E+03
-------------	----------------	-----------------	------------------

FIG. 8 SAMPLE OUTPUT (PROGRAM DROW)

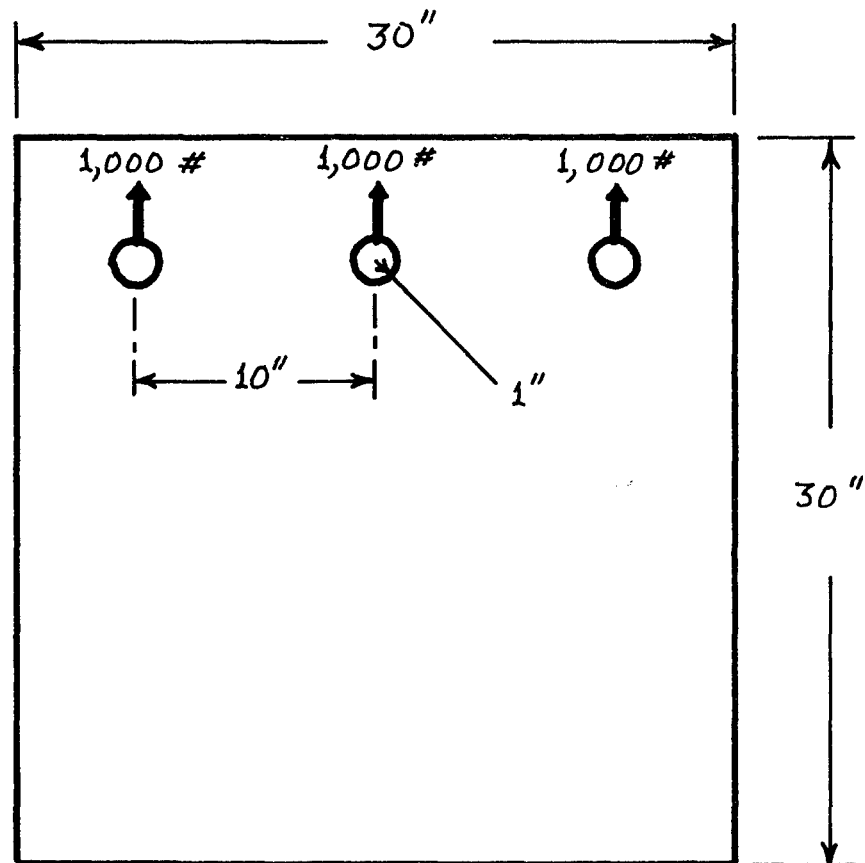


FIG. 9 EXAMPLE OF PANEL WITH ONE ROW OF THREE FASTENER HOLES

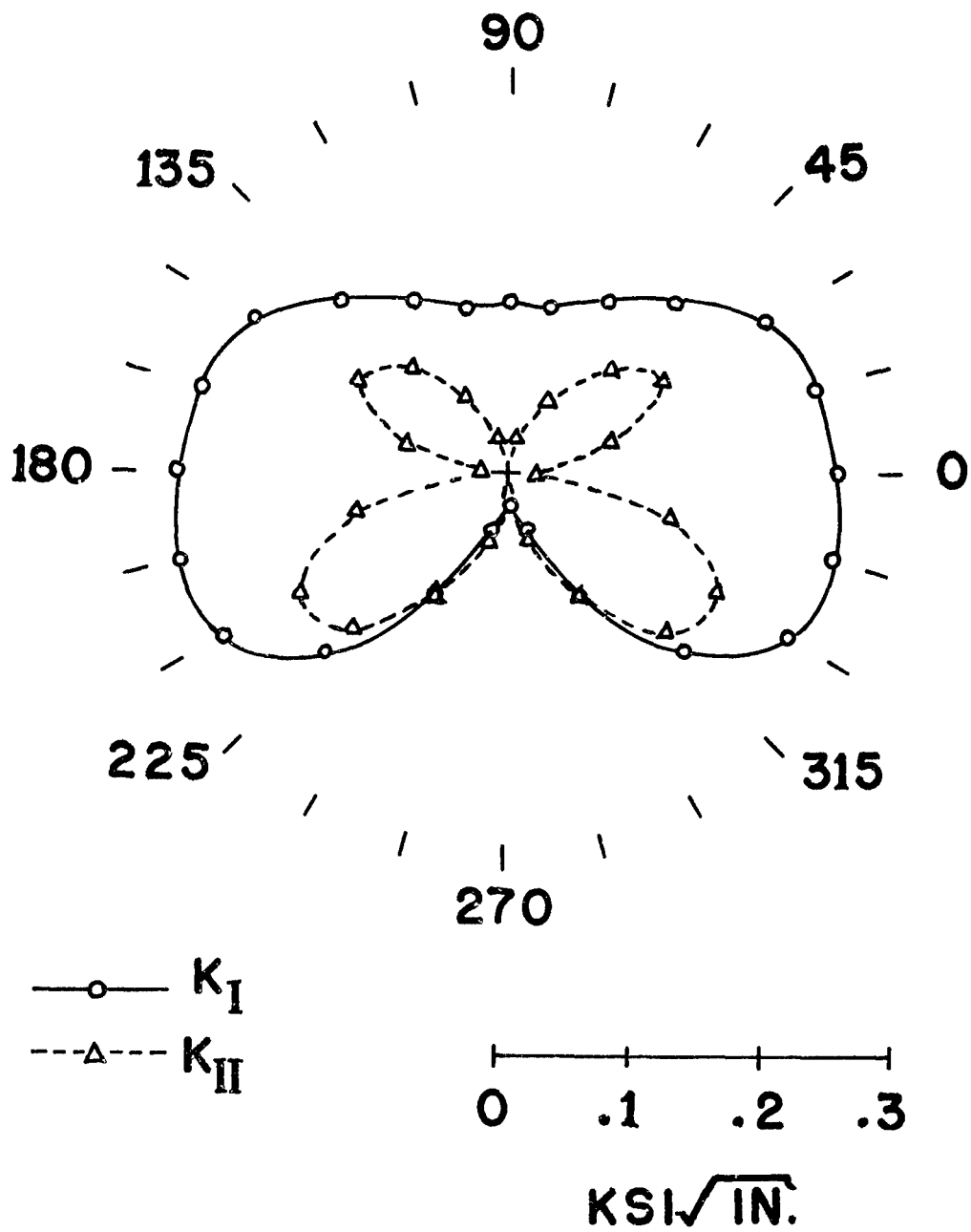


FIG. 10 BUTTERFLY PLOT (CENTER HOLE DAMAGED)

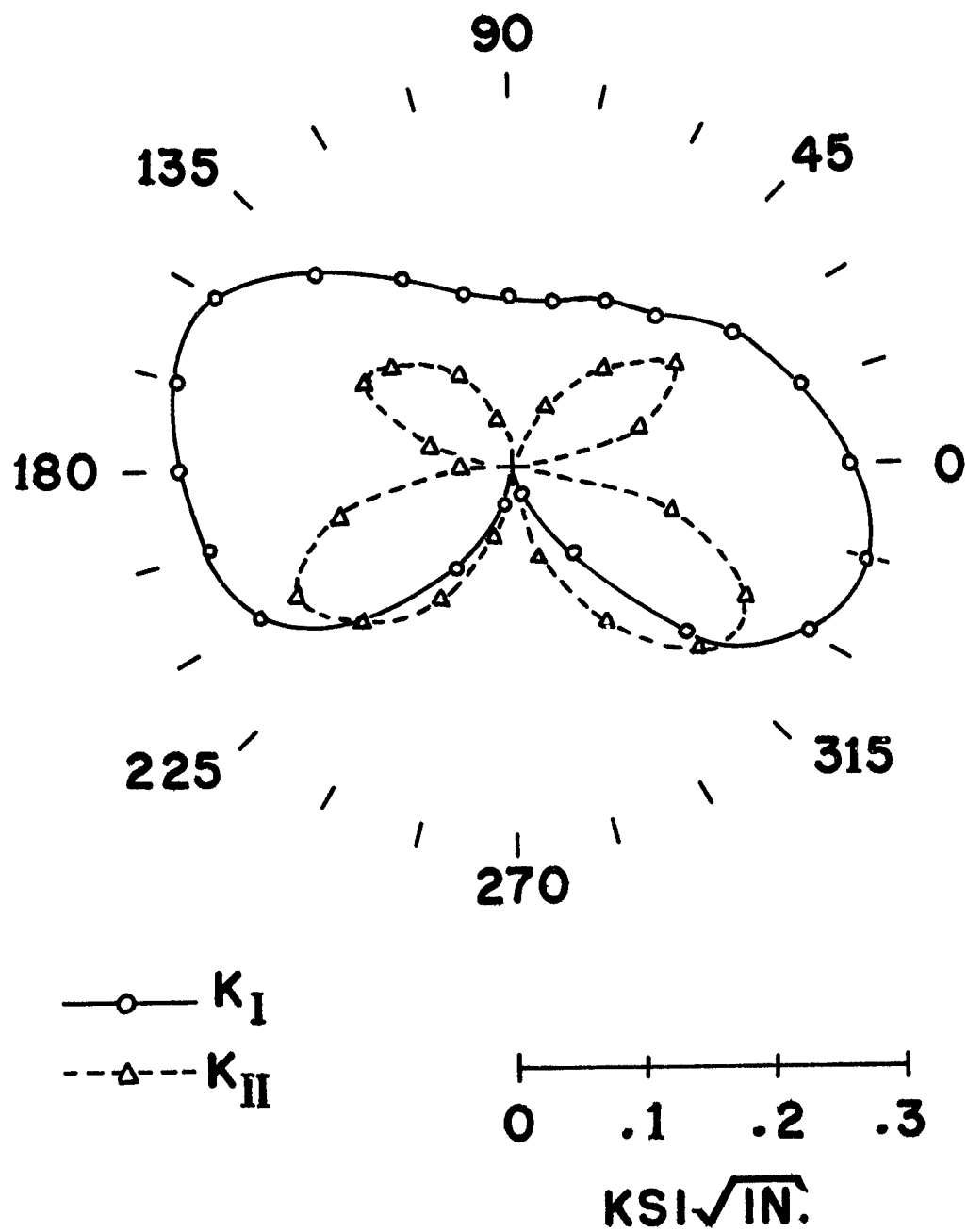


FIG. 11 BUTTERFLY PLOT (RIGHT HOLE DAMAGED)

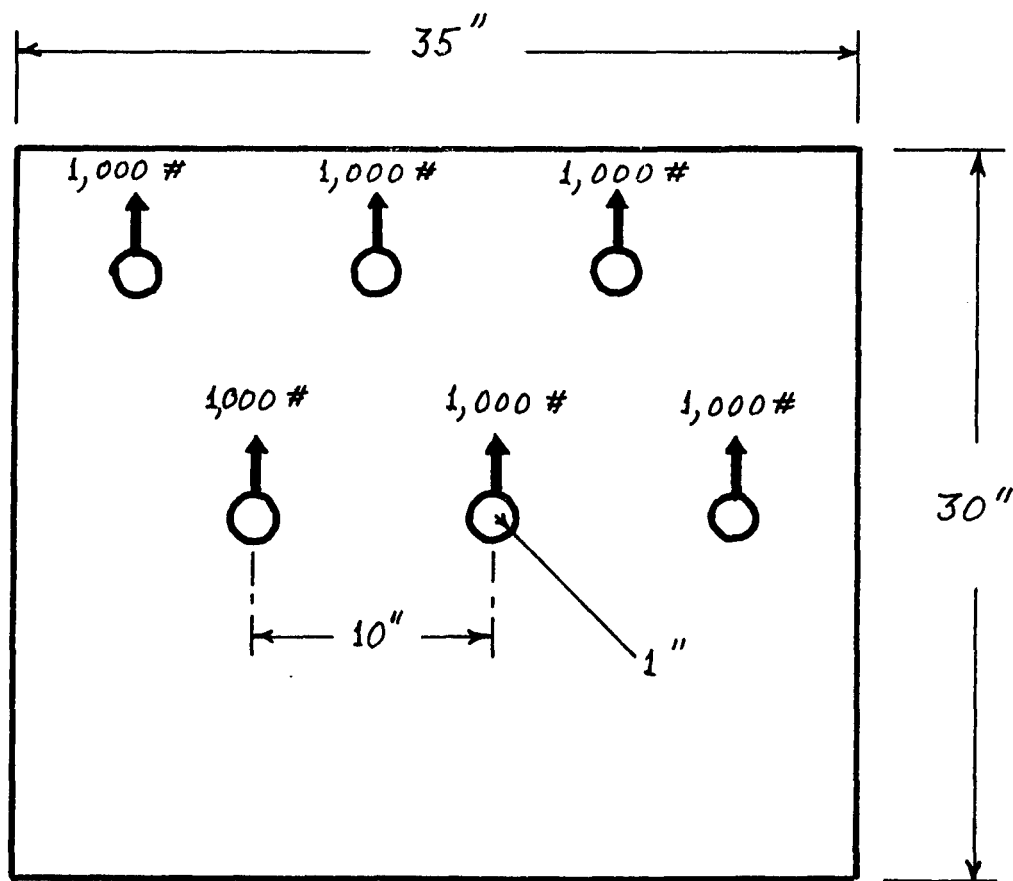


FIG. 12 EXAMPLE OF PANEL WITH TWO ROWS OF THREE FASTENER HOLES

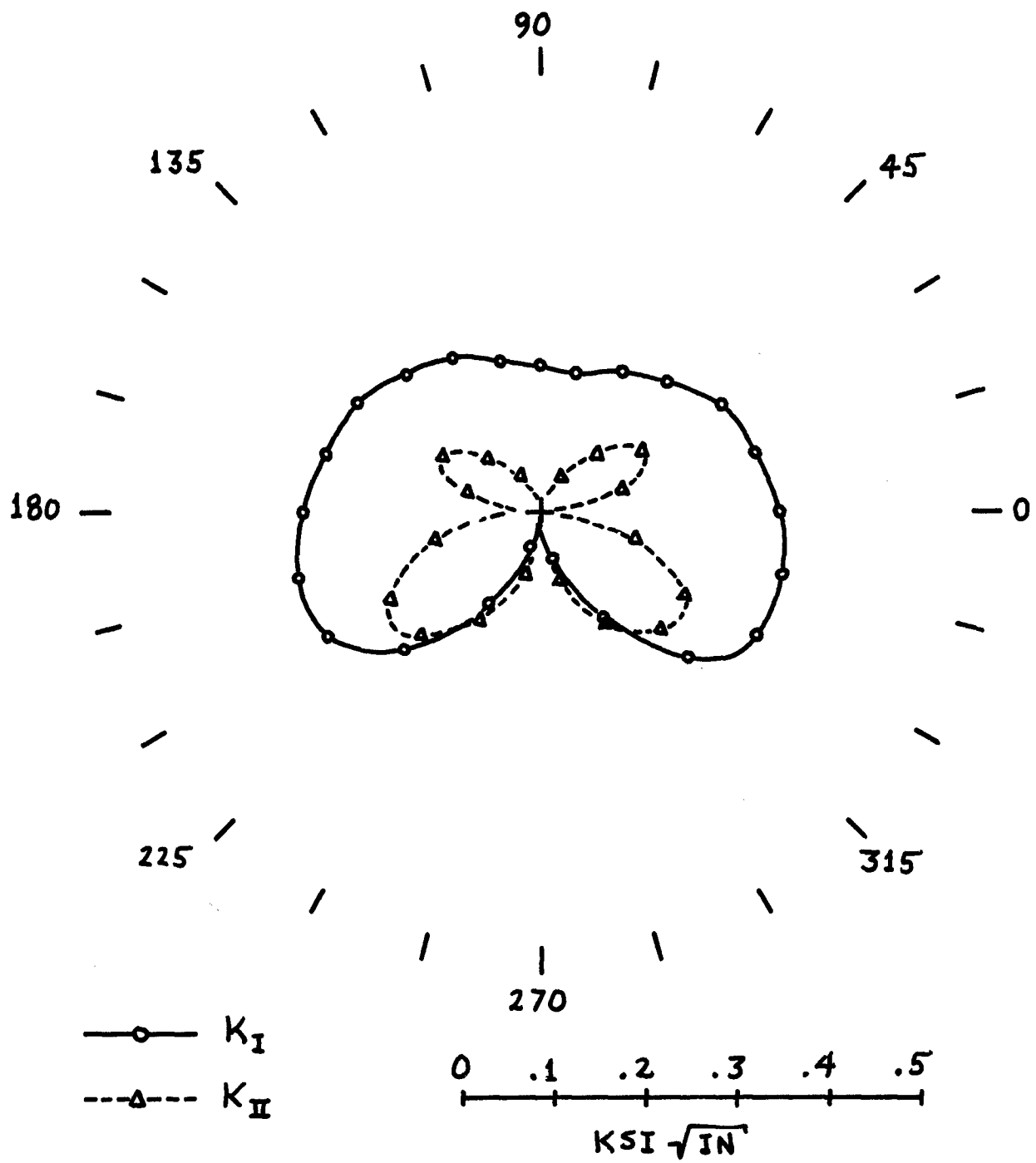


FIG. 13 BUTTERFLY PLOT (CENTER HOLE IN UPPER ROW DAMAGED)

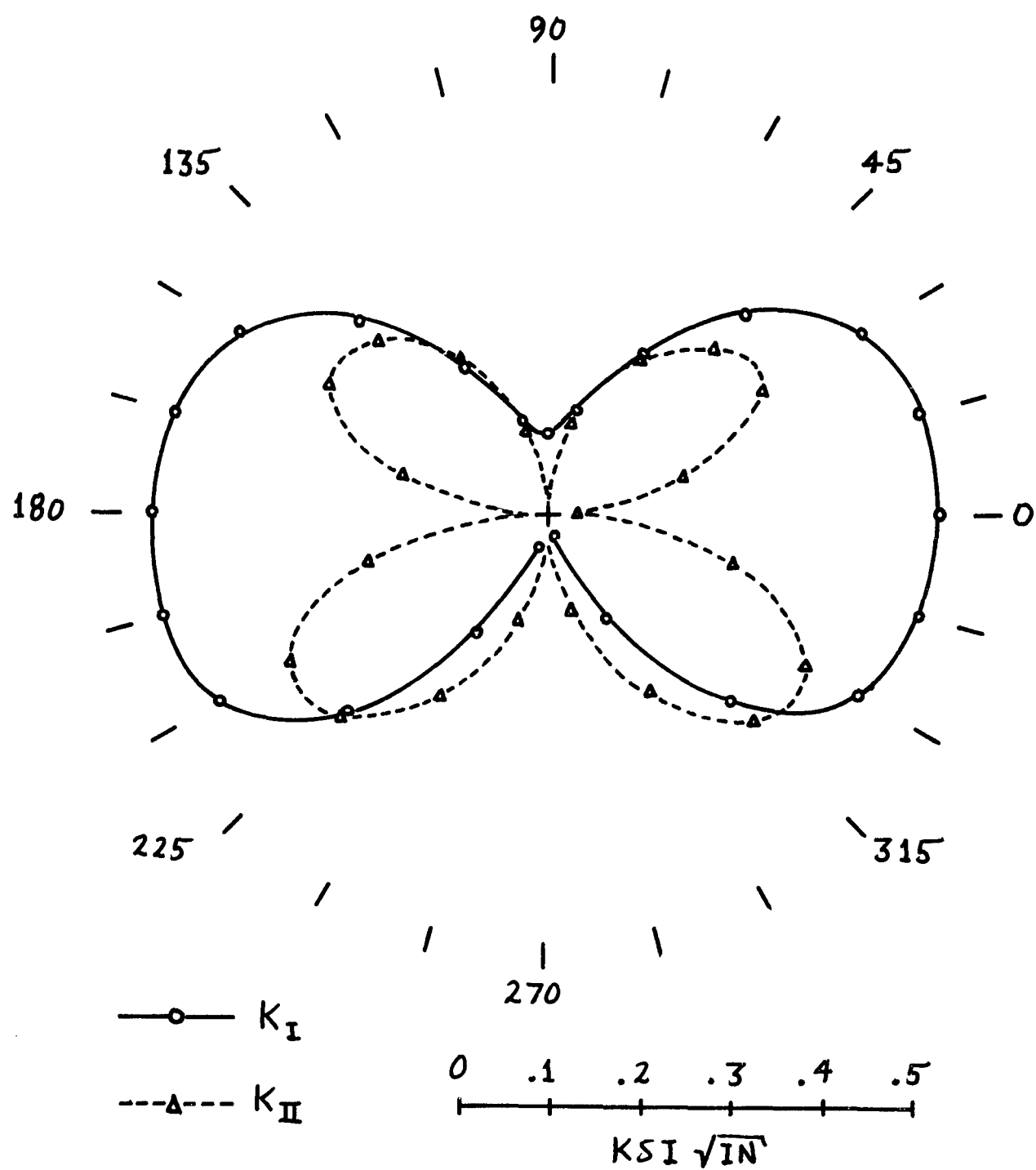


FIG. 14 BUTTERFLY PLOT (CENTER HOLE IN LOWER ROW DAMAGED)

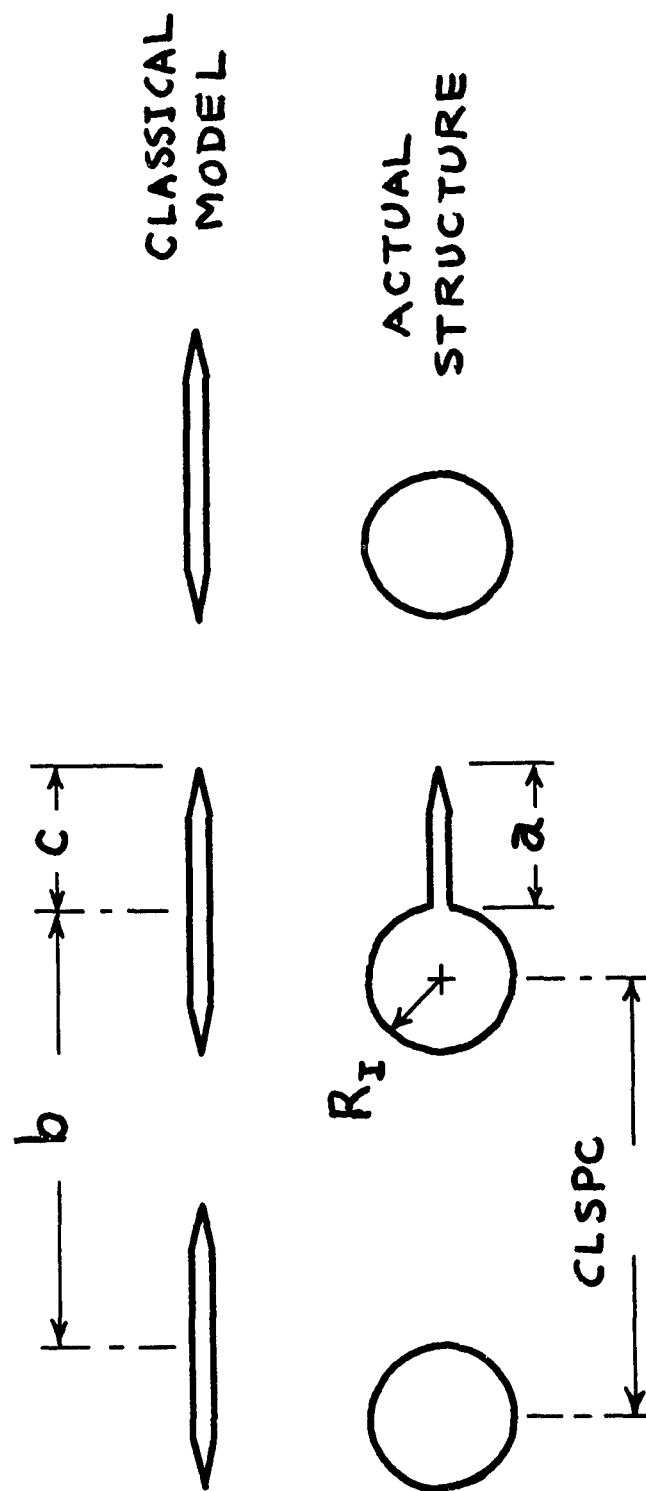


FIG. 15 DEFINITION OF CRACK PARAMETERS FOR CLASSICAL SOLUTIONS

APPENDIX A

```

C TEST MAIN FOR SINGLE ROW OF BOLT HOLES (SROW)
C*****
C COPYRIGHT (C) 1975 MASSACHUSETTS INSTITUTE OF TECHNOLOGY
C AEROELASTIC AND STRUCTURES RESEARCH LABORATORY
C*****
C FINITE ELEMENT APPLICATIONS TO USAF STRUCTURAL INTEGRITY PROBLEMS
C.....INPUT DATA FOR PROBLEM #5 - SINGLE ROW OF BOLT HOLES
C SET      VARIABLES IN SET
C 1      NHOLES,CLSPC,RI,IDMGD,LENGTH,THK
C 2      BFORCE(I), FOR I=1,2,3...NHOLES
C 3      A(1),A(2),IPOS(1),IPOS(2)
C 4      E,GNU
C 5      KT1,KT2,KT3
C =====DEFINITIONS OF INPUT VARIABLES=====
C NHOLES = NO. OF HOLES; CLSPC = CENTER LINE SPACING OF HOLES
C RI = RADIUS OF HOLE; IDMGD = POSITION NO. OF DAMAGED HOLE FROM L.H.S.
C LENGTH = LENGTH OF PLATE; THK = THICKNESS OF PLATE
C BFORCE(I) = MULTIPLIER FOR LOAD IN HOLE I; A(1) = LENGTH OF CRACK ONESROW0018
C A(2) = LENGTH OF CRACK NO. TWO; IPOS(1) = INITIAL POSITION OF CRACK 1SROW0019
C IPOS(2) = FINAL POSITION OF CRACK 1; E = YOUNGS MODULUS;
C GNU = POISSONS RATIO; KT1 = PRINT CONTROL FOR FEABL OPTIONAL PRINT;
C KT2 = PRINT CONTROL FOR OPTIONAL SBL PRINTING
C KT3 = PRINT CONTROL FOR OPTIONAL RING PRINTING
C*****
      DIMENSION RSS(12000),ISS(12000),REAL(8000),INTGR(8000),RRNG(12000)SROW0025
      @.
      @IRNG(12000),A(2),IPOS(2),BFORCE(10),S(3,3),C(3,3),SCALE(2,13),IREGSROW0027
      @IN(6),IEND(6),ISZSS(3),ISZHL(3),IBGBL(6),ISAVE1(2),ISAVE2(6),ISAVESROW0028
      @3(6),ISZ(2),ELO(18),RK(2)
      INTEGER PRNTSV
      REAL LENGTH
      COMMON/IO/KP,KW,KP,KT1,KT2,KT3
      COMMON/SIZE/NET,NDT
      COMMON/BEGIN/ICON,IKOUNT,ILNZ,IMASTR,IQ,IK
      COMMON/END/LCON,LKOUNT,LLNZ,LMASTR,LQ,LK
      COMMON/SIZESS/NETSS,NDTSS,NIDSS

```

```

COMMON/BEGSS/IRGSS(6)
COMMON/MTLPRM/SMU,ETA
COMMON/K1/BCRK(2,2,18)
EQUIVALENCE (RSS(1),ISS(1)),(REAL(1),INTGR(1)),(RRNG(1),IRNG(1)),
@ (ISZ(1),NET),(IBEGIN(1),ICON),(IEND(1),LCON),(ISZSS(1),NETSS)
DATA PI/3.141593/,C/1.0,3*0.0,1.0,4*0.0/,S/1.0,3*0.0,1.0,4*0.0/
DTHETA=PI/12.0
SQRTPI=SQRT(PI)
DATA NSZSS/12000/,NSIZE/ 8000/,NSZRNG/12000/
KR=5
KW=6

C INPUT DATA:
READ(KR,5000) NHOLES,CLSPC,RI,IDMGD,LENGTH,THK
5000 FORMAT(I5,2E10.3,I5,2E10.3)
READ(KR,5001) (BFORCE(I),I=1,NHOLES)
5001 FORMAT(8E10.3)
READ(KR,5002) A(1),A(2),IPOS(1),IPOS(2)
5002 FORMAT(2E10.3,2I5)
READ(KR,5003) E,GNU
5003 FORMAT(2E10.3)
READ(KR,5004) KT1,KT2,KT3
5004 FORMAT(3I5)
WRITE(KW,6000) NHOLES,CLSPC,RI,IDMGD
6000 FORMAT(1H1,56X,16HSINGLE BOLT LINE,/,59X,13HPROBLEM NO. 5,/,/,60XSR0W0060
@,10HINPUT DATA,/,17H NUMBER OF HOLES=,I3,/,30H CENTER LINE SPACINGSR0W0061
@ OF HOLES=,E12.5,/,21H BEARING HOLE RADIUS=,E12.5,/,30H DAMAGED HOSR0W0062
@LE ( FROM L.H.S. )=,I3)
WIDTH=2.0*CLSPC
IF(LENGTH .GE. WIDTH) GO TO 20
WRITE(KW,6001) WIDTH
6001 FORMAT(29H0***** PROGRAM INTERRUPT *****,/,109H USER SPECIFIED PLATSR0W0067
@E DIMENSION LENGTH IS LESS THAN ACCEPTABLE MINIMUM. DIMENSION LESR0W0068
@NGTH WILL BE CHANGED TO ,E12.5/)
LENGTH=WIDTH
20 WIDTH=NHOLES*CLSPC
WRITE(KW,6002) LENGTH,WIDTH,THK

```

```

6002 FORMAT(14H PLATE LENGTH=,E12.5,/,13H PLATE WIDTH=,E12.5,/,17H PLATSROW0073
@E THICKNESS=,E12.5,/,41H BEARING LOADS : HOLE
@/)
DO 30 I=1,NHOLES
30 WRITE(KW,6003) I,RFORCE(I)
6003 FORMAT(1H .20X,I2.5X,E12.5)
NCRK=0
DO 40 I=1,2
40 IF( A(I) .GT. 0.0) NCRK=NCRK+1
WRITE(KW,6004) NCRK
6004 FORMAT(12H0CRACK DATA:./,24H TOTAL NUMBER OF CRACKS=,I2)
IF(NCRK .EQ. 0) GO TO 50
WRITE(KW,6005) (I,A(I),I=1,NCRK)
6005 FORMAT(11H CRACK NO. ,3X,13H CRACK LENGTH,/,5X,I5.4X,E12.5,/,5X,I5.4X,E12.5)
@5,4X,E12.5)
S(3,3)=(IPOS(1)-1)*15.0
S(2,1)=(IPOS(2)-1)*15.0
WRITE(KW,60045) S(3,3),S(2,1)
60045 FORMAT(24H INITIAL CRACK POSITION=,F8.3,25H FINAL CRACK POSITION
@N=,F8.3,42H (+180 DEGREES FOR CRACK NO. 2 POSITION))
50 WRITE(KW,6006) E,GNU
5006 FORMAT(21H0MATERIAL PARAMETERS:./,20H YOUNGS MODULUS (E)=,E12.5,/,
@16H POISSONS RATIO=,F8.3)
SMU=E/(2.0*(1.0+GNU))
ETA =(3.0-GNU)/(1.0+GNU)
C(2,1)=GNU
C(3,3)=(1.0-GNU)/2.0
S(2,1)=-GNU
S(3,3)=(1.0+GNU)*2.0
GNU=E/(1.0-GNU*GNU)
DO 60 I=1,3
DO 60 J=1,I
S(I,J)=S(I,J)/E
S(J,I)=S(I,J)
C(I,J)=C(I,J)*GNU
C(J,I)=C(I,J)
60

```

```

C PRINT OUT PROGRAM STATISTICS TO DATE:
  IF(KT1.EQ. KW ) GO TO 65
  WRITE(KW,6007) WIDTH,SMU,ETA
6007 FORMAT(20H0PROGRAM STATISTICS:./,13H PLATE WIDTH=.E12.5,/,5H SMU=,
  @E12.5,/,5H ETA=.E12.5,/,9H S MATRIX,/)
  WRITE(KW,6008) ((S(I,J),J=1,3),I=1,3)
6008 FORMAT(1H .3E12.5)
  WRITE(KW,6009)
6009 FORMAT(10H0C MATRIX:)
  WRITE(KW,6008) ((C(I,J),J=1,3),I=1,3)
C CONSTRUCT SINGLE ROLT LINE STRUCTURE:
65 PRNTSV=KT1
  KT1=KT2
  LENGTH=LENGTH-CLSPC
  CALL SBL(THK,RI,S,BFORCE,NHOLES,IDMGD,CLSPC,LENGTH,WIDTH,NELW,
  @SCALE,NSZSS,RSS,ISS,NSZRNG,RRNG,IRNG,C)
  DO 260 I=1,2
  DO 260 J=1,13
260 SCALE(I,J)=SCALE(I,J)*BFORCE(IDMGD)
  KT1=PRNTSV
  DO 180 I=1,3
180 ISZBL(I)=ISZSS(I)
  DO 190 I=1,6
190 IBGBL(I)=IBEGIN(I)
C
C
C CHESIRE CAT REMAINS
C SET UP CRACK PROBLEM:
  NET=2
  NDT=96+NCRK*2
  NCON=146+NCRK*2
  CALL SETUP(NSIZE,I,NCON,REAL,INTGR)
C ELEMENT NO. 1 IS CHESIRE CAT
  IPNTR=IMASTR+NET
  INTGR(IMASTR)=IPNTR
  DO 200 I=1,48

```

```

SROW0109
SROW0110
SROW0111
SROW0112
SROW0113
SROW0114
SROW0115
SROW0116
SROW0117
SROW0118
SROW0119
SROW0120
SROW0121
SROW0122
SROW0123
SROW0124
SROW0125
SROW0126
SROW0127
SROW0128
SROW0129
SROW0130
SROW0131
SROW0132
SROW0133
SROW0134
SROW0135
SROW0136
SROW0137
SROW0138
SROW0139
SROW0140
SROW0141
SROW0142
SROW0143
SROW0144

```

```

        INTGR(IPNTR)=I
200  IPNTR=IPNTR+1
      C ELEMENT NO. 2 IS THE CRACKED RING
        JLOC=IPOS(1)
        INTGR(IMASTR+1)=IPNTR
205  IPNTR=INTGR(IMASTR+1)
      DO 206 I=49,NDT
        INTGR(IPNTR)=I
206  IPNTR=IPNTR+1
        J=(JLOC+4)*2-1
        IF(JLOC .GE. 21) J=(JLOC-20)*2-1
      DO 210 I=J,48
        INTGR(IPNTR)=I
210  IPNTR=IPNTR+1
        J=J-1
        IF(JLOC .EQ. 21) GO TO 225
      DO 220 I=1,J
        INTGR(IPNTR)=I
220  IPNTR=IPNTR+1
225  CONTINUE
        IF(KT1 .EQ. KW ) GO TO 230
        J=IMASTR+1
        WRITE(KW,6013) (INTGR(I),I=IMASTR,J)
6013 FORMAT(41H0MASTER ASSEMBLY LIST FOR CRACK PROBLEM :/,10H POINTERSSROW0168
      @:./,32H ELEMENT NO. 1 ( CHESIRE CAT ) =,I5,/,33H FLEMENT NO. 2 ( CSROW0169
      @RACKED RING ) =,I5,/)
        J=J+1
        IPNTR=J+47
        WRITE(KW,6014) (INTGR(I),I=J,IPNTR)
6014 FORMAT(38H ELEMENT NO. 1 (CHESIRE CAT) D.O.F.S: ,16I5,/,37X,16I5,/,SROW0174
      @,37X,16I5)
        IPNTR=IPNTR+1
        WRITE(KW,6015) (INTGR(I),I=IPNTR,LMASTR)
6015 FORMAT(40H0ELEMENT NO. 2 ( CRACKED RING ) D.O.F.S: ,16I5,/,37X,16I5SROW0177
      @,/,37X,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5)
230  CALL ORK(NSIZE,REAL,INTGR)
      SROW0145
      SROW0146
      SROW0147
      SROW0148
      SROW0149
      SROW0150
      SROW0151
      SROW0152
      SROW0153
      SROW0154
      SROW0155
      SROW0156
      SROW0157
      SROW0158
      SROW0159
      SROW0160
      SROW0161
      SROW0162
      SROW0163
      SROW0164
      SROW0165
      SROW0166
      SROW0167
      SROW0168
      SROW0169
      SROW0170
      SROW0171
      SROW0172
      SROW0173
      SROW0174
      SROW0175
      SROW0176
      SROW0177
      SROW0178
      SROW0179
      SROW0180

```

```

240 DO 240 I=1,3
    ISZSS(I)=ISZBL(I)
250 DO 250 I=1,6
    IRGSS(I)=IRGBL(I)
    CALL ASMSUB(1,RSS,ISS,REAL,INTGR)
    THTCRK=DTHETA*(JLOC-1)
    PRNTSV=KT1
    KT1=KT3
    INDCTR=0
    CALL RING(RI,THK,THTCRK,NCRK,A(1),A(2),INDCTR,S,C,NSZRNG,RRNG,IRNGS
    @)
    KT1=PRNTSV
    CALL ASMSUB(2,RRNG,IRNG,REAL,INTGR)
    C APPLY REMAINING BEARING LOAD:
    IF (JLOC .GT. 13) GO TO 290
    J=JLOC+1
    IF (JLOC .EQ. 13) GO TO 275
    IDOF=IQ-47+NDT
    DO 270 I=J,13
    REAL(IDOF-1)=SCALE(1,I)
    REAL(IDOF)=SCALE(2,I)
    IDOF=IDOF+2
270 IDOF=NDT-(JLOC-1)*2+IQ-1
275 J=J-1
    IF (JLOC .EQ. 13) J=13
    DO 280 I=1,J
    REAL(IDOF-1)=SCALE(1,I)
    REAL(IDOF)=SCALE(2,I)
    IDOF=IDOF+2
280 IF (NCRK .EQ. 0) GO TO 310
    REAL(IQ-2+NDT)=REAL(IQ-2+NDT)/2.0
    REAL(IQ-1+NDT)=REAL(IQ-1+NDT)/2.0
    REAL(IQ-50+NDT)=REAL(IQ-2+NDT)
    REAL(IQ-49+NDT)=REAL(IQ-1+NDT)
    IF (NCRK .EQ. 1) GO TO 310
    IF (JLOC .NE. 1 .AND. JLOC .NE. 13) GO TO 310

```

```

SROW0181
SROW0182
SROW0183
SROW0184
SROW0185
SROW0186
SROW0187
SROW0188
SROW0189
SROW0190
SROW0191
SROW0192
SROW0193
SROW0194
SROW0195
SROW0196
SROW0197
SROW0198
SROW0199
SROW0200
SROW0201
SROW0202
SROW0203
SROW0204
SROW0205
SROW0206
SROW0207
SROW0208
SROW0209
SROW0210
SROW0211
SROW0212
SROW0213
SROW0214
SROW0215
SROW0216

```



```

REAL(IQ-26+NDT)=REAL(IQ-26+NDT)/2.0
REAL(IQ-25+NDT)=REAL(IQ-25+NDT)/2.0
REAL(IQ-52+NDT)=REAL(IQ-26+NDT)
REAL(IQ-51+NDT)=REAL(IQ-25+NDT)
GO TO 310
290 IDOF=NDT-25-(JLOC-13)*2 +IQ
DO 300 I=1,13
REAL(IDOF-1)=SCALE(1,I)
REAL(IDOF)=SCALE(2,I)
300 IDOF=IDOF+2
IF(NCRK .NE. 2) GO TO 310
REAL(IQ-26+NDT)=REAL(IQ-26+NDT)/2.0
REAL(IQ-25+NDT)=REAL(IQ-25+NDT)/2.0
REAL(IQ-52+NDT)=REAL(IQ-26+NDT)
REAL(IQ-51+NDT)=REAL(IQ-25+NDT)
C OBTAIN SOLUTION:
310 I=1
CALL FACT(I,REAL,INTGR)
CALL SIMULO(GNU,REAL,INTGR)
C OBTAIN CRACKED RING INTERIOR DISPLACEMENTS:
CALL QBACK(2,RRNG,IRNG,REAL,INTGR)
IF(NCRK .EQ. 0) GO TO 360
WRITE(KW,60145)
60145 FORMAT(1H0)
DO 320 I=1,6
ISAVE2(I)=IBEGIN(I)
IBEGIN(I)=IRGSS(I)
320 THTCRK=THTCRK*180.0/PI
DO 350 I=1,NCRK
CALL XTRACT(I+18,18,ELQ,RRNG,IRNG)
DO 330 J=1,2
RK(J)=0.0
DO 330 K=1,18
330 RK(J)=RK(J)+BCRK(I,J,K)*ELQ(K)
DO 340 J=1,2
340 RK(J)=RK(J)*SQRTPI

```

```

SROW0217
SROW0218
SROW0219
SROW0220
SROW0221
SROW0222
SROW0223
SROW0224
SROW0225
SROW0226
SROW0227
SROW0228
SROW0229
SROW0230
SROW0231
SROW0232
SROW0233
SROW0234
SROW0235
SROW0236
SROW0237
SROW0238
SROW0239
SROW0240
SROW0241
SROW0242
SROW0243
SROW0244
SROW0245
SROW0246
SROW0247
SROW0248
SROW0249
SROW0250
SROW0251
SROW0252

```

SROW0253
 SROW0254
 SROW0255
 SROW0256
 SROW0257
 SROW0258
 SROW0259
 SROW0260
 SROW0261
 SROW0262
 SROW0263
 SROW0264

```

    RK(2)=ABS(RK(2))
    WRITE(KW,6016) I,THTCRK,(RK(J),J=1,2)
    6016 FORMAT(11H CRACK NO. ,I2,9H  ANGLE=,F8.3,8H  KI=,E12.5,9H
           @KII=,E12.5)
    350 THTCRK=THTCRK+180.0
    C INCREMENT CRACK POSITION:
    360 JLOC=JLOC+1
    DO 370 I=1,6
    370 IBEGIN(I)=ISAVE2(I)
    IF(JLOC .LE. IPOS(2)) GO TO 205
    STOP
    END
  
```

```

SUBROUTINE SBL (THK,RI,S,BFORCE,NHOLES,IDMGD,CLSPC,LENGTH,WIDTH,
@NELW,SCALE,NSIZE,RSS,ISS,NSZHL,RHOLE,IHOLE,C)
C*****
C*****
C*****
C SUBROUTINE SBL (SINGLE BOLT LINE) CREATES A FINITE ELEMENT MODEL OF
C A ROW OF FASTENER HOLES ALONG THE TOP EDGE OF A PLATE. ONE HOLE MUST
C CONTAIN AT LEAST ONE CRACK.
C*****
C COPYRIGHT (C) 1975 MASSACHUSETTS INSTITUTE OF TECHNOLOGY
C AEROELASTIC AND STRUCTURES RESEARCH LABORATORY
C*****
C FINITE ELEMENT APPLICATIONS TO USAF STRUCTURAL INTEGRITY PROBLEMS
DIMENSION RSS(1),ISS(1),RHOLE(2097),IHOLE(2097),S(3,3),NODE(8),
@BFORCE(1),SCALE(2,13),COORD(12),B(6,3,13),C(3,3),ISAVE1(2),ISAVE2(
@6),ISAVE3(6),ISZ(2)
REAL LENGTH
INTEGER CNODE,CNSTRN (48)
COMMON/IO/KR,KW,KP,KT1,KT2,KT3
COMMON/SIZE/NET,NDT
COMMON/BEGIN/IREGIN(6)
COMMON/END/IENTD(6)
COMMON/SIZESS/NETSS,NDTSS,NID
COMMON/BEGSS/IRGSS(6)
EQUIVALENCE (NET,ISZ(1))
DATA PI/3.141593/
DO 5 I=1,12
COORD(I)=0.0
NDW=2*NHOLES+1
NET=NHOLES+1
NDT=(3*NDW+(NHOLES+1)*24)*2
WIDTH=CLSPC/8.0
IF(RI .GT. WIDTH) GO TO 170
WIDTH=CLSPC/12.0
IF(RI .LT. WIDTH) GO TO 180
COORD(1)=CLSPC
COORD(4)=CLSPC
SBL 0000
SBL 0001
SBL 0002
SBL 0003
SBL 0004
SBL 0005
SBL 0006
SBL 0007
SBL 0008
SBL 0009
SBL 0010
SBL 0011
SBL 0012
SBL 0013
SBL 0014
SBL 0015
SBL 0016
SBL 0017
SBL 0018
SBL 0019
SBL 0020
SBL 0021
SBL 0022
SBL 0023
SBL 0024
SBL 0025
SBL 0026
SBL 0027
SBL 0028
SBL 0029
SBL 0030
SBL 0031
SBL 0032
SBL 0033
SBL 0034
SBL 0035

```

```

COORD(5)=CLSPC
COORD(8)=CLSPC
WIDTH=NHOLES*CLSPC
NELW=2*NHOLES
NCON=2*NHOLES+48-NDW+1
LMASTR=NHOLES*65+4*NDW+1
NIDSS=NDT-48
IF( KTL .EQ. KW ) GO TO 10
WRITE(KW,6000) THK,RI,NHOLES,IDMGD,CLSPC,(BFORCE(I),I=1,NHOLES)
6000 FORMAT(1H1.61X,9HENTRY SBL,///,23H SUBROUTINE INPUT DATA:,,17H PSBL
@LATE THICKNESS=,E12.5,/,21H BEARING HOLE RADIUS=,E12.5,/,23H TOTALSBL
@ NUMBER OF HOLES=,I5,/,36H I.D. OF DAMAGED HOLE (FROM L.H.S.)=,I5,SBL
@/,21H CENTER LINE SPACING=,E12.5,/,20H BEARING FORCE(LBS):,12E10.3SBL
@)
WRITE(KW,6001) WIDTH,NELW,(COORD(I),I=1,12)
6001 FORMAT(23H0SUBROUTINE STATISTICS:,,24H CALCULATED PLATE WIDTH=,E1SBL
@2.5,/,46H NUMBER OF QUADRILATERALS NEEDED ACROSS WIDTH=,I5,/,20H HSBL
@OLE ELEMENT COORD:.,12F3.3)
10 CALL SETUP(NSIZE,NCON,LMASTR,RSS,ISS)
IMASTR=IBEGIN(4)
IPNTR=IMASTR+NET
CNODE=NHOLES*26
DO 40 N=1,NHOLES
NM1=N-1
ISS(IMASTR+NM1)=IPNTR
NODER=CNODE-1
NODL=CNODE+1
NODE(1)=NODER+2*NDW
NODE(2)=NODER
NODE(3)=NODER+NDW
NODE(4)=CNODE+NDW
NODE(5)=NODL+NDW
NODE(6)=NODL
NODE(7)=NODL+2*NDW
NODE(8)=CNODE+2*NDW
DO 20 I=1,8

```

```

SBL 0036
SBL 0037
SBL 0038
SBL 0039
SBL 0040
SBL 0041
SBL 0042
SBL 0043
SBL 0044
SBL 0045
SBL 0046
SBL 0047
SBL 0048
SBL 0049
SBL 0050
SBL 0051
SBL 0052
SBL 0053
SBL 0054
SBL 0055
SBL 0056
SBL 0057
SBL 0058
SBL 0059
SBL 0060
SBL 0061
SBL 0062
SBL 0063
SBL 0064
SBL 0065
SBL 0066
SBL 0067
SBL 0068
SBL 0069
SBL 0070
SBL 0071

```

20	IDOF=NODE(I)*2	SBL 0072
	ISS(IPNTR)=IDOF-1	SBL 0073
	ISS(IPNTR+1)=IDOF	SBL 0074
	IPNTR=IPNTR+2	SBL 0075
	MODEL=NM1*48+1	SBL 0076
	NODE=NODEL+47	SBL 0077
	DO 30 I=NODEL,NODER	SBL 0078
	ISS(IPNTR)=I	SBL 0079
30	IPNTR=IPNTR+1	SBL 0080
40	CNODE=CNODE-2	SBL 0081
	IPNTR=ISS(IMASTR+IDMGD-1)+16	SBL 0082
	NODE=IPNTR+47	SBL 0083
	NODEL=NDT-47	SBL 0084
	J=1	SBL 0085
	DO 50 I=IPNTR,NODER	SBL 0086
	CNSTRN (J)=ISS(I)	SBL 0087
	ISS(I)=NODEL	SBL 0088
	J=J+1	SBL 0089
50	NODEL=NODEL+1	SBL 0090
	NMBRCN=1	SBL 0091
	DO 51 I=1,NDW	SBL 0092
	ISS(NMBRCN)=CNSTRN (I*2)	SBL 0093
51	NMBRCN=NMBRCN+1	SBL 0094
	ISS(NMBRCN)=CNSTRN ((NELW/2+1)*2-1)	SBL 0095
	IPNTR=ISS(IMASTR+NHOLES-1)+64	SBL 0096
	ISS(IMASTR+NHOLES)=IPNTR	SBL 0097
	NODEL=2*NDW	SBL 0098
	DO 52 I=1,NODEL	SBL 0099
	ISS(IPNTR)=CNSTRN (I)	SBL 0100
52	IPNTR=IPNTR+1	SBL 0101
	NODEL=NHOLES*48+4*NDW+1	SBL 0102
	NODE=NODEL+2*NELW+1	SBL 0103
	DO 53 I=NODEL,NODER	SBL 0104
	ISS(IPNTR)=I	SBL 0105
53	IPNTR=IPNTR+1	SBL 0106
	IF (KTI .EQ. KW) GO TO 70	SBL 0107


```

KT1=KT2
CALL LUG(WIDTH,LENGTH,NELW,THK,THK,C,NSZHL,RHOLE,IHOLE)
KT1=CNODE
DO 88 I=1,2
  ISZ(I)=ISAVE1(I)
DO 89 I=1,6
  IBEGIN(I)=ISAVE2(I)
  IEND(I)=ISAVE3(I)
CALL ASMSUB(NHOLES+1,RHOLE,IHOLE,RSS,ISS)
IMASTR=IBEGIN(5)-1
CNODE=NHOLES*52
NCON=NMBRCN+1
DO 100 N=1,NHOLES
  ISS(NCON)=CNODE
  ISS(NCON+1)=CNODE-1
  RSS(IMASTR+ISS(NCON))=0.0
  RSS(IMASTR+ISS(NCON+1))=0.0
  NCON=NCON+2
CNODE=CNODE-4
NODEL=2*NDW+1
DO 105 I=NODEL,48
  ISS(NCON)=CNSTRN (I)
  NCON=NCON+1
  NCON=NCON-1
DO 106 I=1,NCON
  RSS(IMASTR+ISS(I))=0.0
  DTHETA=PI/24.0
  DTHT=PI/12.0
  PO=2.0/(RI*THK*PI)
  THETA=0.0
DO 120 I=1,7
  SS1=SIN(THETA-DTHETA)
  SS2=SIN(THETA+DTHETA)
  IF( I.EQ. 1 ) SS1=0.0
  IF( I.EQ. 13 ) SS2=0.0
  PNODE=PO*THK*DTHETA*(SS2+SS1)*RI

```

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0144

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```

IF( KTI .EQ. KW ) GO TO 110
WRITE(KW,6004) I,PNODE
6004 FORMAT(41H0CONSISTENT PP NODAL FORCE: GENERAL NODE ,I3,28H SCALED SBL 0180
@ P (XBEARING FORCE)=,E12.5) SBL 0181
110 SCALE(2,I)=PNODE*SIN(THETA) SBL 0182
SCALE(1,I)=PNODE*COS(THETA) SBL 0183
IF (KTI .EQ. KW ) GO TO 120 SBL 0184
WRITE(KW,6005) I,(SCALE(J,I),J=1,2) SBL 0185
6005 FORMAT(21H0SCALE FACTORS: NODE ,I3,9H X SCALE=,E12.5,11H Y SCALE SBL 0186
@=,E12.5) SBL 0187
120 THETA=THETA+DTHT SBL 0188
DO 125 I=8,13 SBL 0189
IMASTR=14-I SBL 0190
DO 125 J=1,2 SBL 0191
SCALE(J,I)=SCALE(J,IMASTR) SBL 0192
DO 126 I=8,13 SBL 0193
SCALE(1,I)=-SCALE(1,I) SBL 0194
SCALE(1,7)=0.0 SBL 0195
IF (NHOLES .EQ. 1) GO TO 145 SBL 0196
MODEL=7 SBL 0197
IMASTR=IBEGIN(5)-1 SBL 0198
DO 140 N=1,NHOLES SBL 0199
IF( N .EQ. IDMGD ) GO TO 140 SBL 0200
DO 130 I=1,13 SBL 0201
DO 130 J=1,2 SBL 0202
RSS(IMASTR+MODEL)=SCALE(J,I)*BFORCE(N) SBL 0203
130 MODEL=MODEL+1 SBL 0204
140 MODEL=N*48+7 SBL 0205
145 CALL BCON(RSS,ISS) SBL 0206
I=1 SBL 0207
CALL STACON(I,NIDSS,RSS,ISS) SBL 0208
DO 150 I=1,6 SBL 0209
IBGSS(I)=IBEGIN(I) SBL 0210
NETSS=NET SBL 0211
NDTSS=NDT SBL 0212
NID=NIDSS SBL 0213
SBL 0214
SBL 0215

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```

IF (KT1.EQ. KW) GO TO 160
WRITE(KW,6006)
6006 FORMAT(1H0,61X,8HEXIT SRL)
160 RETURN
170 WRITE(KW,6007) RI,CLSPC
6007 FORMAT(56H0*****PROGRAM INTERRUPT INITIATED BY SUBROUTINE SRL *****SRL
@,/,27H USER SPECIFIED DIMENSIONS:/,10X,13H HOLE RADIUS=.E12.5,/,SRL
@10X,30H CENTER LINE SPACING OF HOLES=.E12.5,/,87H SUCH DIMENSIONSSRL
@ WILL CAUSE UNACCEPTABLE PROBLEMS WITH HOLE ELEMENT AND MUST BE ALSRL
@TERED,/,21H RECOMMENDED CHANGES:,//)
CLSPC=8.0*RI
WRITE(KW,6008) WIDTH,CLSPC
6008 FORMAT(33H LET RI BE LESS THAN OR EQUAL TO ,E12.5,56H OR LET CENTESRL
@R LINE SPACING BE GREATER THAN OR EQUAL TO ,E12.5)
GO TO 190
180 WRITE(KW,6007) RI,CLSPC
CLSPC=12.0*RI
WRITE(KW,6009) WIDTH,CLSPC
6009 FORMAT(36H LET RI BE GREATER THAN OR EQUAL TO ,E12.5,53H OR LET CESRL
@ENTER LINE SPACING BE LESS THAN OR EQUAL TO ,E12.5)
190 WRITE(KW,6010)
6010 FORMAT(51H0***** EXECUTION TERMINATED IN SUBROUTINE SRL *****SRL
STOP
END
SRL 0216
SRL 0217
SRL 0218
SRL 0219
SRL 0220
SRL 0221
SRL 0222
SRL 0223
SRL 0224
SRL 0225
SRL 0226
SRL 0227
SRL 0228
SRL 0229
SRL 0230
SRL 0231
SRL 0232
SRL 0233
SRL 0234
SRL 0235
SRL 0236
SRL 0237
SRL 0238
SRL 0239

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```

C TEST MAIN FOR DOUBLE ROW OF BOLT HOLES (DROW)
C *****
C COPYRIGHT (C) 1975 MASSACHUSETTS INSTITUTE OF TECHNOLOGY
C AEROELASTIC AND STRUCTURES RESEARCH LABORATORY
C *****
C FINITE ELEMENT APPLICATIONS TO USAF STRUCTURAL INTEGRITY PROBLEMS
C .....INPUT DATA FOR PROBLEM #6 - DOUBLE ROW OF BOLT HOLES.....
C SET      VARIABLES IN SET      FORMAT FOR EACH CARD
C 1      NHOLES,CLSPC,RI,IROW,IDMGD,LENGTH,THK (15,2E10.3,2I5,2E10.3)DROW0009
C 2      BFORCE(I), FOR I=1,2,3...NHOLES (FOR ROW 1) (8E10.3)DROW0010
C 3      BFORCE(I), FOR I=1,2,3...NHOLES (FOR ROW 2) (8E10.3)DROW0011
C 4      A(1),A(2),IPOS(1),IPOS(2) (2E10.3,2I5)DROW0012
C 5      E,GNU (2E10.3)DROW0013
C 6      KT1,KT2,KT3 (3I5)DROW0014
C =====DEFINITIONS OF INPUT VARIABLES=====
C NHOLES = NO. OF HOLES; CLSPC = CENTER LINE SPACING OF HOLES
C RI = RADIUS OF HOLE; IROW = ROW CONTAINING DAMAGED HOLE (FROM TOP)
C IDMGD = POSITION NO. OF DAMAGED HOLE FROM L.H.S.
C LENGTH = LENGTH OF PLATE; THK = THICKNESS OF PLATE
C BFORCE(I) = MULTIPLIER FOR LOAD IN HOLE I; A(1) = LENGTH OF CRACK ONE
C A(2) = LENGTH OF CRACK NO. TWO; IPOS(1) = INITIAL POSITION OF CRACK 1
C IPOS(2) = FINAL POSITION OF CRACK 1; E = YOUNGS MODULUS;
C GNU = POISSONS RATIO; KT1 = PRINT CONTROL FOR FEABL OPTIONAL PRINT;
C KT2 = PRINT CONTROL FOR OPTIONAL DBL PRINTING
C KT3 = PRINT CONTROL FOR OPTIONAL RING PRINTING
C *****
      DIMENSION RSS(30000),ISS(30000),REAL(8000),INTGR(8000),RRNG(12000)DROW0026
      @,IRNG(12000),A(2),IPOS(2),BFORCE(20),S(3,3),C(3,3),SCALE(2,13),IBEDROW0028
      @GIN(6),IEND(6),ISZSS(3),ISZBL(3),IBGBL(6),ISAVE1(2),ISAVE2(6),ISAVDROW0029
      @E3(6),ISZ(2),ELQ(18),RK(2)
      INTEGER PRNTSV
      REAL LENGTH
      COMMON/IO/KR,KW,KP,KT1,KT2,KT3
      COMMON/SIZE/NET,NDT
      COMMON/BEGIN/ICON,IKOUNT,ILNZ,IMASTR,IQ,IK
      COMMON/END/LCON,LKOUNT,LLNZ,LMASTR,LQ,LK

```

```

COMMON/SIZESS/NETSS,NDTSS,NIDSS
COMMON/BEGSS/IRGSS(6)
COMMON/MILPRM/SMU,ETA
COMMON/KI/RCKK(2,2,18)
EQUIVALENCE (RSS(1),ISS(1)),(REAL(1),INTGR(1)),(RPRNG(1),IRNG(1)),
@ (ISZ(1),NET), (IBEGIN(1),ICON), (IEND(1),LCON), (ISZSS(1),NETSS)
DATA PI/3.141593/,C/1.0,3*0.0,1.0,4*0.0/,S/1.0,3*0.0,1.0,4*0.0/
DTHETA=PI/12.0
SQRTPI=SQRT(PI)
DATA NSZSS/30000/,NSIZE/ 8000/,NSZRNG/12000/
KR=5
KW=6

C INPUT DATA:
READ (KR,5000) NHOLES,CLSPC,RI,IROW,IDMGD,LENGTH,THK
5000 FORMAT(I5,2E10.3,2I5,2E10.3)
DO 10 I=1,2
  J1=(I-1)*NHOLES+1
  J2=J1+NHOLES-1
  10 READ(KR,5001) (BFORCE(J),J=J1,J2)
5001 FORMAT(8E10.3)
  NH2=2*NHOLES
  READ(KR,5002) A(1),A(2),IPOS(1),IPOS(2)
5002 FORMAT(2E10.3,2I5)
  READ(KR,5002) E,GNU
  READ(KR,5004) KT1,KT2,KT3
5004 FORMAT(3I5)
  WRITE(KW,6000) NHOLES,CLSPC,RI,IROW,IDMGD
6000 FORMAT(1H1,56X,16HD0URLF BOLT LINE,/,59X,13HPROBLEM NO. 6,/,/,60X,
@,10HINPUT DATA,/,25H NUMBER OF HOLES PER ROW=,I3,/,30H CENTER LINEDROW0065
@ SPACING OF HOLES=,E12.5,/,21H BEARING HOLE RADIUS=,E12.5,/,20H DADROW0066
@MAGED HOLE IN ROW,12,3H IS,I3,12H FROM L.H.S.)
  WIDTH=3.*CLSPC
  IF(LENGTH.GE. WIDTH) GO TO 20
  WRITE(KW,6001) WIDTH
6001 FORMAT(29H0***** PROGRAM INTERRUPT *****,/,109H USER SPECIFIED PLATDROW0071
@E DIMENSION LENGTH IS LESS THAN ACCEPTABLE MINIMUM. DIMENSION LEDROW0072

```

```

        LENGTH WILL BE CHANGED TO ,E12.5/)
        LENGTH=WIDTH
        WIDTH=NHOLES*CLSPC+.5*CLSPC
        WRITE(KW,6002) LENGTH,WIDTH,THK
6002  FORMAT(14H PLATE LENGTH=,E12.5,/,13H PLATE WIDTH=,E12.5,/,17H PLATDROW0073
        @E THICKNESS=,E12.5,/,41H BEARING LOADS :      HOLE      FORCE(LBS),DROW0074
        @/)DROW0075
        DO 32 NROW=1,2DROW0076
        DO 30 I=1,NHOLES
        J=I+(NROW-1)*NHOLES
        WRITE(KW,6003) NROW,I,BFORCE(J)
        CONTINUE
6003  FORMAT(1H ,9X,4HROW=,I2,4X,I2,5X,E12.5)
        NCRK=0
        DO 40 I=1,2
        IF( A(I) .GT. 0.0) NCRK=NCRK+1
        WRITE(KW,6004) NCRK
6004  FORMAT(12H0CRACK DATA: ,/,24H TOTAL NUMBER OF CRACKS=,I2)
        IF(NCRK .EQ. 0 ) GO TO 50
        WRITE(KW,6005) (I,A(I),I=1,NCRK)
6005  FORMAT(11H CRACK NO. ,3X,13H CRACK LENGTH,/,5X,I5,4X,E12.5,/,5X,1DROW0093
        @5,4X,E12.5)
        S(3,3)=(IP0S(1)-1)*15.0
        S(2,1)=(IP0S(2)-1)*15.0
        WRITE(KW,60045) S(3,3),S(2,1)
60045  FORMAT(24H INITIAL CRACK POSITION=,F8.3,25H      FINAL CRACK POSITIONDROW0098
        @N=,F8.3,42H      (+180 DEGREES FOR CRACK NO. 2 POSITION))
        WRITE(KW,6006) E,GNU
        FORMAT(21H0MATERIAL PARAMETERS: ,/,20H YOUNGS MODULUS (E)=,E12.5,/,DROW0100
        @16H POISSONS RATIO=,F8.3)
        SMU=E/(2.0*(1.0+GNU))
        ETA =(3.0-GNU)/(1.0+GNU)
        C(2,1)=GNU
        C(3,3)=(1.0-GNU)/2.0
        S(2,1)=-GNU
        S(3,3)=(1.0+GNU)*2.0
DROW0101
DROW0102
DROW0103
DROW0104
DROW0105
DROW0106
DROW0107
DROW0108

```

```

GNU=E/(1.0-GNU*GNU)
DO 60 I=1,3
DO 60 J=1,I
S(I,J)=S(I,J)/E
S(J,I)=S(I,J)
C(I,J)=C(I,J)*GNU
60 C(J,I)=C(I,J)
C PRINT OUT PROGRAM STATISTICS TO DATE:
IF(KT1.EQ. KW ) GO TO 65
WRITE(KW,6007) WIDTH,SMU,ETA
6007 FORMAT(20H0PROGRAM STATISTICS: ,/,13H PLATE WIDTH=,E12.5,/,5H SMU=,
@E12.5,/,5H ETA=,E12.5,/,9H S MATRIX,/)
WRITE(KW,6008) ((S(I,J),J=1,3),I=1,3)
6008 FORMAT(1H ,3F12.5)
WRITE(KW,6009)
6009 FORMAT(10H0C MATRIX:)
WRITE(KW,6008) ((C(I,J),J=1,3),I=1,3)
C CONSTRUCT SINGLE HOLT LINE STRUCTURE:
65 PRNTSV=KT1
KT1=KT2
LENGTH=LENGTH-2.*CLSPC
CALL DBL(THK,RI,S,BFORCE,NHOLES,IROW,IDMGD,CLSPC,LENGTH,WIDTH,NELW
@,SCALE,NSZSS,RSS,ISS,NS7RNG,RRNG,IRNG,C)
IDM=(IROW-1)*NHOLES+IDMGD
DO 260 I=1,2
DO 260 J=1,13
260 SCALE(I,J)=SCALE(I,J)*BFORCE(IDM)
KT1=PRNTSV
DO 180 I=1,3
180 ISZBL(I)=ISZSS(I)
DO 190 I=1,6
190 IBGBL(I)=IREGIN(I)
C
C
C CHESIRE CAT REMAINS
C SET UP CRACK PROBLEM:

```

```

DROW0109
DROW0110
DROW0111
DROW0112
DROW0113
DROW0114
DROW0115
DROW0116
DROW0117
DROW0118
DROW0119
DROW0120
DROW0121
DROW0122
DROW0123
DROW0124
DROW0125
DROW0126
DROW0127
DROW0128
DROW0129
DROW0130
DROW0131
DROW0132
DROW0133
DROW0134
DROW0135
DROW0136
DROW0137
DROW0138
DROW0139
DROW0140
DROW0141
DROW0142
DROW0143
DROW0144

```

```

NET=2
NDT=96+NCRK*2
NCON=146+NCRK*2
CALL SETUP(NSIZE,1,NCON,REAL,INTGR)
C ELEMENT NO. 1 IS CHESIRE CAT
IPNTR=IMASTR+NET
INTGR(IMASTR)=IPNTR
DO 200 I=1,48
  INTGR(IPNTR)=I
  IPNTR=IPNTR+1
  200
C ELEMENT NO. 2 IS THE CRACKED RING
JLOC=IPOS(1)
INTGR(IMASTR+1)=IPNTR
  205 IPNTR=INTGR(IMASTR+1)
  DO 206 I=49,NDT
    INTGR(IPNTR)=I
    IPNTR=IPNTR+1
    206 J=(JLOC+4)*2-1
    IF(JLOC.GE. 21) J=(JLOC-20)*2-1
    DO 210 I=J,48
      INTGR(IPNTR)=I
      IPNTR=IPNTR+1
      210 J=J-1
      IF(JLOC.EQ. 21) GO TO 225
      DO 220 I=1,J
        INTGR(IPNTR)=I
        IPNTR=IPNTR+1
        220
      225 CONTINUE
      IF(KT1.EQ. KW) GO TO 230
      J=IMASTR+1
      WRITE(KW,6013) (INTGR(I),I=IMASTR,J)
      6013 FORMAT(41H0MASTER ASSEMBLY LIST FOR CRACK PROBLEM :/,10H POINTERSDROW0176
@:./,32H ELEMENT NO. 1 ( CHESIRE CAT ) =,I5,/,33H ELEMENT NO. 2 ( CDROW0177
@RACKED RING ) =,I5,/)
      J=J+1
      IPNTR=J+47
DROW0145
DROW0146
DROW0147
DROW0148
DROW0149
DROW0150
DROW0151
DROW0152
DROW0153
DROW0154
DROW0155
DROW0156
DROW0157
DROW0158
DROW0159
DROW0160
DROW0161
DROW0162
DROW0163
DROW0164
DROW0165
DROW0166
DROW0167
DROW0168
DROW0169
DROW0170
DROW0171
DROW0172
DROW0173
DROW0174
DROW0175
DROW0176
DROW0177
DROW0178
DROW0179
DROW0180

```

```

WRITE(KW,6014) (INTGR(I),I=J,IPNTR)
6014 FORMAT(38H ELEMENT NO. 1 (CHESIRE CAT) D.O.F.S: ,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5)
@,37X,16I5)
IPNTR=IPNTR+1
WRITE(KW,6015) (INTGR(I),I=IPNTR,LMASTR)
6015 FORMAT(40H0ELEMENT NO. 2 ( CRACKED RING ) D.O.F.S: ,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5)
@,/,37X,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5,/,37X,16I5)
230 CALL ORK(NSIZE,REAL,INTGR)
DO 240 I=1,3
240 ISZSS(I)=ISZBL(I)
DO 250 I=1,6
250 IBGSS(I)=IRGBL(I)
CALL ASMSUB(1,RSS,ISS,REAL,INTGR)
THICRK=DTHETA*(JLOC-1)
PRNTSV=KT1
KT1=KT3
INDCTR=0
CALL RING(RI,THK,THICRK,NCRK,A(1),A(2),INDCTR,S,C,NSZRNG,RRNG,IRNGDROW0198
@)
KT1=PRNTSV
CALL ASMSUB(2,RRNG,IRNG,REAL,INTGR)
C APPLY REMAINING BEARING LOAD:
IF(JLOC .GT. 13) GO TO 290
J=JLOC+1
IF(JLOC .EQ. 13) GO TO 275
IDOF=IQ-47+NDT
DO 270 I=J,13
REAL(IDOF-1)=SCALE(1,I)
REAL(IDOF)=SCALE(2,I)
270 IDOF=IDOF+2
275 IDOF=NDT-(JLOC-1)*2+IQ-1
J=J-1
IF(JLOC .EQ. 13) J=13
DO 280 I=1,J
REAL(IDOF-1)=SCALE(1,I)
REAL(IDOF)=SCALE(2,I)

```

```

280 IDOF=IDOF+2
   IF(NCRK.EQ. 0) GO TO 310
   REAL(IQ-2+NDT)=REAL(IQ-2+NDT)/2.0
   REAL(IQ-1+NDT)=REAL(IQ-1+NDT)/2.0
   REAL(IQ-50+NDT)=REAL(IQ-2+NDT)
   REAL(IQ-49+NDT)=REAL(IQ-1+NDT)
   IF(NCRK.EQ. 1) GO TO 310
   IF(JLOC.NE. 1.AND. JLOC.NE. 13) GO TO 310
   REAL(IQ-26+NDT)=REAL(IQ-26+NDT)/2.0
   REAL(IQ-25+NDT)=REAL(IQ-25+NDT)/2.0
   REAL(IQ-52+NDT)=REAL(IQ-26+NDT)
   REAL(IQ-51+NDT)=REAL(IQ-25+NDT)
   GO TO 310

290 IDOF=NDT-25-(JLOC-13)*2 +IQ
   DO 300 I=1,13
   REAL(IDOF-1)=SCALE(1,I)
   REAL(IDOF)=SCALE(2,I)
   IDOF=IDOF+2
   IF(NCRK.NE. 2) GO TO 310
   REAL(IQ-26+NDT)=REAL(IQ-26+NDT)/2.0
   REAL(IQ-25+NDT)=REAL(IQ-25+NDT)/2.0
   REAL(IQ-52+NDT)=REAL(IQ-26+NDT)
   REAL(IQ-51+NDT)=REAL(IQ-25+NDT)

   C OBTAIN SOLUTION:
310 I=1
   CALL FACT(I,REAL,INTGR)
   CALL SIMULQ(GNU,REAL,INTGR)

   C OBTAIN CRACKED RING INTERIOR DISPLACEMENTS:
   CALL QBACK(2,RRNG,IRNG,REAL,INTGR)
   IF(NCRK.EQ. 0) GO TO 360
   WRITE(KW,60145)
60145 FORMAT(1H0)
   DO 320 I=1,6
   ISAVE2(I)=IBEGIN(I)
   IBEGIN(I)=IBGSS(I)
320 THTCRK=THTCRK*180.0/PI

```

```

DROW0217
DROW0218
DROW0219
DROW0220
DROW0221
DROW0222
DROW0223
DROW0224
DROW0225
DROW0226
DROW0227
DROW0228
DROW0229
DROW0230
DROW0231
DROW0232
DROW0233
DROW0234
DROW0235
DROW0236
DROW0237
DROW0238
DROW0239
DROW0240
DROW0241
DROW0242
DROW0243
DROW0244
DROW0245
DROW0246
DROW0247
DROW0248
DROW0249
DROW0250
DROW0251
DROW0252

```



```

DO 350 I=1,NCRK
CALL XTRACT(I+18,18,ELQ,RRNG,IRNG)
DO 330 J=1.2
RK(J)=0.0
DO 330 K=1.18
330 RK(J)=RK(J)+BCRK(I,J,K)*ELQ(K)
DO 340 J=1.2
340 RK(J)=RK(J)*SQRTPI
RK(2)=ABS(RK(2))
WRITE(KW,6016) I,THTCRK,(RK(J),J=1,2)
6016 FORMAT(11H CRACK NO. ,I2.9H ANGLE=,F8.3,8H
@KII=,E12.5)
350 THTCRK=THTCRK+180.0
C INCREMENT CRACK POSITION:
360 JLLOC=JLLOC+1
DO 370 I=1.6
370 IBEGIN(I)=ISAVE2(I)
IF(JLLOC.LE. IPOS(2)) GO TO 205
STOP
END

```

KI=,E12.5,9H

DROW0253
DROW0254
DROW0255
DROW0256
DROW0257
DROW0258
DROW0259
DROW0260
DROW0261
DROW0262
DROW0263
DROW0264
DROW0265
DROW0266
DROW0267
DROW0268
DROW0269
DROW0270
DROW0271
DROW0272

```

SUBROUTINE DBL (THK,RI,S,BFORCE,NHOLES,IROW,IDMGD,CLSPC,LENGTH,WIDTDBL 0000
@H,NELW,SCALE,NSIZE,RSS,ISS,NSZHL,RHOLE,IHOLE,C) DBL 0001
C***** DBL 0002
C SUBROUTINE DBL (DOUBLE BOLT LINE) CREATES A FINITE ELEMENT MODEL OF DBL 0003
C 2 ROWS OF FASTENER HOLES ALONG THE TOP EDGE OF A PLATE. ONE HOLE MUST DBL 0004
C CONTAIN AT LEAST ONE CRACK. DBL 0005
C***** DBL 0006
C COPYRIGHT (C) 1975 MASSACHUSETTS INSTITUTE OF TECHNOLOGY DBL 0007
C AEROELASTIC AND STRUCTURES RESEARCH LABORATORY DBL 0008
C FINITE ELEMENT APPLICATIONS TO USAF STRUCTURAL INTEGRITY PROBLEMS DBL 0009
C THIS DOUBLE BOLT LINE SUBROUTINE IS A MODIFICATION OF GEORGE STALKS DBL 0010
C SUBROUTINE SBL WHICH IS FOR A SINGLE BOLT LINE DBL 0011
C DIMENSION RSS(1),ISS(1),RHOLE(2097),IHOLE(2097),S(3,3),NODE(8), DBL 0012
@BFORCE(1),SCALE(2,13),COORD(12),B(6,3,13),C(3,3),ISAVE1(2),ISAVE2(DBL 0013
@6),ISAVE3(6),ISZ(2),XY(12),EF(8),ELK(36),BMAT(3,9) DBL 0014
REAL LENGTH DBL 0015
INTEGER CNODE,CNSTRN (48) DBL 0016
COMMON/IO/KR,KW,KP,KT1,KT2,KT3 DBL 0017
COMMON/SIZE/NET,NDT DBL 0018
COMMON/BEGIN/IREGIN(6) DBL 0019
COMMON/END/IEND(6) DBL 0020
COMMON/SIZESS/NETSS,NDTSS,NID DBL 0021
COMMON/BEGSS/IBGSS(6) DBL 0022
EQUIVALENCE (NET,ISZ(1)) DBL 0023
DATA PI/3.141593/ DBL 0024
DO 5 I=1,12 DBL 0025
XY(I)=0. DBL 0026
COORD(I)=0.0 DBL 0027
NDW=2*NHOLES+2 DBL 0028
NET=2*NHOLES+5 DBL 0029
NDT=116*NHOLES+68 DBL 0030
WIDTH=CLSPC/8.0 DBL 0031
IF(RI .GT. WIDTH) GO TO 170 DBL 0032
WIDTH=CLSPC/12.0 DBL 0033
IF(RI .LT. WIDTH) GO TO 180 DBL 0034
C COORDINATES FOR HOLE SUBSTRUCTURE DBL 0035

```

```

COORD(1)=CLSPC
COORD(4)=CLSPC
COORD(5)=CLSPC
COORD(8)=CLSPC
C COORDINATES FOR QUAD4 ELEMENT
WIDTH=.5*CLSPC
XY(1)=WIDTH
XY(4)=WIDTH
XY(5)=WIDTH
XY(8)=WIDTH
WIDTH=NHOLES*CLSPC+WIDTH
NELW=2*NHOLES+1
NH2=2*NHOLES
NCON=48+NH2
LMASTR=2*65*NHOLES+9*4+4*NDW+1
NIDSS=NDT-48
IF( KTL .EQ. KW ) GO TO 10
WRITE(KW,6000) THK,RI,NH2,IDMGD,IROW,CLSPC,(BFORCE(I),I=1,NH2)
6000 FORMAT(1H1,61X,9HENTRY DBL,/,23H SUBROUTINE INPUT DATA:,,17H PDRL
@LATE THICKNESS=.E12.5,/,21H BEARING HOLE RADIUS=.E12.5,/,23H TOTALDBL
@ NUMBER OF HOLES=,I5,/,36H I.D. OF DAMAGED HOLE (FROM L.H.S.)=,I5,DBL
@8H IN ROW=.I2,/,21H CENTER LINE SPACING=.E12.5,/,20H BEARING FORCEDBL
@ (LBS):,12E10.3,/,1H ,RE10.3)
WRITE(KW,6001) WIDTH,NELW,(COORD(I),I=1,12)
6001 FORMAT(23H0SUBROUTINE STATISTICS:,,24H CALCULATED PLATE WIDTH=.E1DBL
@2.5,/,46H NUMBER OF QUADRILATERALS NEEDED ACROSS WIDTH=,I5,/,20H HDBL
@OLE ELEMENT COORD:,,12F8.3)
10 CALL SETUP(NSIZE,NCON,LMASTR,RSS,ISS)
IMASTR=IBEGIN(4)
IPNTR=IMASTR+NET
CNODE=50*NHOLES+1
K1=2*NDW
K2=NDW
N1=1
N2=NHOLES
DO 42 NROW=1,2

```

```

DBL 0036
DBL 0037
DBL 0038
DBL 0039
DBL 0040
DBL 0041
DBL 0042
DBL 0043
DBL 0044
DBL 0045
DBL 0046
DBL 0047
DBL 0048
DBL 0049
DBL 0050
DBL 0051
DBL 0052
DBL 0053
DBL 0054
DBL 0055
DBL 0056
DBL 0057
DBL 0058
DBL 0059
DBL 0060
DBL 0061
DBL 0062
DBL 0063
DBL 0064
DBL 0065
DBL 0066
DBL 0067
DBL 0068
DBL 0069
DBL 0070
DBL 0071

```

```

DO 40 N=N1,N2
C MASTER LIST FOR HOLE SUBSTRUCTURES
NM1=N-1
ISS(IMASTR+NM1)=IPNTR
NODER=CNODE-1
NODEL=CNODE+1
NODE(1)=NODER+K1
NODE(2)=NODER
NODE(3)=NODER+K2
NODE(4)=CNODE+K2
NODE(5)=NODEL+K2
NODE(6)=NODEL
NODE(7)=NODEL+K1
NODE(8)=CNODE+K1
DO 20 I=1,8
IDOF=NODE(I)*2
ISS(IPNTR)=IDOF-1
ISS(IPNTR+1)=IDOF
IPNTR=IPNTR+2
NODEL=NM1*48+1
NODER=NODEL+47
DO 30 I=NODEL,NODER
ISS(IPNTR)=I
IPNTR=IPNTR+1
CNODE=CNODE-2
CNODE=56*NHOLES+6
K1=NDW
K2=-NDW
N1=N2+1
N2=NH2
42 N2=NH2
C MASTER LIST FOR QUAD4 ELEMENTS
NM1=IMASTR+NH2-1
DO 49 IEL=1,4
ISS(NM1+IEL)=IPNTR
GO TO (43,44,45,46), IEL
43 NODE(1)=48*NHOLES+1

```

```

DBL 0072
DBL 0073
DBL 0074
DBL 0075
DBL 0076
DBL 0077
DBL 0078
DBL 0079
DBL 0080
DBL 0081
DBL 0082
DBL 0083
DBL 0084
DBL 0085
DBL 0086
DBL 0087
DBL 0088
DBL 0089
DBL 0090
DBL 0091
DBL 0092
DBL 0093
DBL 0094
DBL 0095
DBL 0096
DBL 0097
DBL 0098
DBL 0099
DBL 0100
DBL 0101
DBL 0102
DBL 0103
DBL 0104
DBL 0105
DBL 0106
DBL 0107

```

```

NODE(2)=NODE(1)+NDW
NODE(3)=NODE(2)+1
NODE(4)=NODE(1)+1
GO TO 47
44 NODE(2)=NODE(1)
   NODE(3)=NODE(4)
   NODE(1)=NODE(2)+2*NDW
   NODE(4)=NODE(1)+1
GO TO 47
45 NODE(2)=NODE(1)+NDW-2
   NODE(3)=NODE(2)+1
   NODE(4)=NODE(3)+NDW
   NODE(1)=NODE(4)-1
GO TO 47
46 NODE(2)=NODE(1)
   NODE(3)=NODE(4)
   NODE(1)=NODE(2)+NDW
   NODE(4)=NODE(1)+1
47 DO 48 I=1,4
   KDOF=2*NODE(I)
   ISS(IPNTR)=KDOF-1
   ISS(IPNTR+1)=KDOF
48 IPNTR=IPNTR+2
49 CONTINUE
C STORE DOF NUMBERS ORIGINALLY ASSIGNED TO INSIDE OF DAMAGED HOLE
IDM=(IROW-1)*NHOLES+IDMGD
IPNTR=ISS(IMASTR+IDM-1)+16
NODER=IPNTR+47
NODEL=NDT-47
J=1
DO 50 I=IPNTR,NODER
  CNSTRN (J)=ISS(I)
  ISS(I)=NODEL
  J=J+1
50 NODEL=NODEL+1
C CONSTRAIN ALL VERTICAL DOFS ON BOTTOM EDGE

```

```

DBL 0108
DBL 0109
DBL 0110
DBL 0111
DBL 0112
DBL 0113
DBL 0114
DBL 0115
DBL 0116
DBL 0117
DBL 0118
DBL 0119
DBL 0120
DBL 0121
DBL 0122
DBL 0123
DBL 0124
DBL 0125
DBL 0126
DBL 0127
DBL 0128
DBL 0129
DBL 0130
DBL 0131
DBL 0132
DBL 0133
DBL 0134
DBL 0135
DBL 0136
DBL 0137
DBL 0138
DBL 0139
DBL 0140
DBL 0141
DBL 0142
DBL 0143

```

```

NMBRCN=1
DO 51 I=1,NDW
  ISS(NMBRCN)=CNSTRN (I*2)
  NMBRCN=NMBRCN+1
51 C CONSTRAIN THE HORIZONTAL DOFS AT THE PAIR OF CENTER NODES ON BOTTOM
  ISS(NMBRCN)=CNSTRN(NELW)
  NMBRCN=NMBRCN+1
  ISS(NMBRCN)=CNSTRN(NELW+2)
  IPNTR=ISS(IMASTR+NH2+3)+8
  ISS(IMASTR+NH2+4)=IPNTR
C RE-ASSIGN DOF NUMBERS AROUND DAMAGED HOLE TO BOTTOM EDGE OF LUG SURSTR
  NODEL=2*NDW
DO 52 I=1,NODEL
  ISS(IPNTR)=CNSTRN (I)
  IPNTR=IPNTR+1
52 C REPLACE THE DOF NUMBERS ORIGINALLY ASSIGNED TO THE DAMAGED HOLE WITH
  C THE HIGHEST DOF NUMBERS WHICH WILL REMAIN WHEN ALL OTHERS ARE CONDENSED
  NODEL=96*NOLES+8*NDW+1
  NODEL=NODEL+2*NELW+1
DO 53 I=NODEL,NODER
  ISS(IPNTR)=I
  IPNTR=IPNTR+1
53 IF ( KTI .EQ. KW ) GO TO 70
  IMASTR=IBEGIN(4)
  LMASTR=IMASTR+NET-1
  WRITE(KW,6002) (ISS(I),I=IMASTR,LMASTR)
6002 FORMAT(22H0MASTER ASSEMBLY LIST: ,/ ,10H POINTERS: ,20I5)
  IMASTR=LMASTR+1
  LMASTR=IMASTR+63
DO 60 N=1,NH2
  WRITE(KW,6003) N,(ISS(I),I=IMASTR,LMASTR)
6003 FORMAT(17H0HOLE ELEMENT NO. ,I3,10H D.O.F.S: ,/ ,15X,9HBOUNDARY: ,16I0
  @5, / ,15X,15H0HOLE INTERIOR: ,16I5, / ,30X,16I5, / ,30X,16I5)
  IMASTR=LMASTR+1
  LMASTR=IMASTR+63
60 LMASTR=IMASTR+31

```

```

DBL 0144
DBL 0145
DBL 0146
DBL 0147
DBL 0148
DBL 0149
DBL 0150
DBL 0151
DBL 0152
DBL 0153
DBL 0154
DBL 0155
DBL 0156
DBL 0157
DBL 0158
DBL 0159
DBL 0160
DBL 0161
DBL 0162
DBL 0163
DBL 0164
DBL 0165
DBL 0166
DBL 0167
DBL 0168
DBL 0169
DBL 0170
DBL 0171
DBL 0172
DBL 0173
DBL 0174
DBL 0175
DBL 0176
DBL 0177
DBL 0178
DBL 0179

```

60030	WRITE(KW,60030) (ISS(I),I=IMASTR,LMASTR)	DBL 0180
	FORMAT(14H0QUAD4 S DOFS:,16I6,/,1H0,15X,16I6)	DBL 0181
	IMASTR=LMASTR+1	DBL 0182
	LMASTR=IEND(4)	DBL 0183
60031	WRITE(KW,60031)	DBL 0184
	FORMAT(21H0LUG ELEMENT 0.0.F.S:)	DBL 0185
60032	WRITE(KW,60032) (RSS(I),I=IMASTR,LMASTR)	DBL 0186
70	FORMAT(1H .20I5)	DBL 0187
	CALL ORK(NSIZE,RSS,ISS)	DBL 0188
	CALL QUAD4(XY,THK,COORD,C,0,NODE,COORD,EF,ELK,BMAT,1,KW)	DBL 0189
	C ASSEMBLE FOUR QUAD4S	DBL 0190
	N1=NH2+1	DBL 0191
	N2=N1+3	DBL 0192
	DO 72 N=N1,N2	DBL 0193
72	CALL ASMLTV(N,8,ELK,EF,RSS,ISS)	DBL 0194
	NCON=KT1	DBL 0195
	KT1=KW	DBL 0196
	CALL HOLEL(COORD,THK,S,RI,RHOLE,IHOLE,B)	DBL 0197
	C ASSEMBLE UNDEAMAGED HOLES	DBL 0198
	DO 80 N=1,NH2	DBL 0199
	IF(N.EQ. IDM) GO TO 80	DBL 0200
	CALL ASMSUB(N,RHOLE,IHOLE,RSS,ISS)	DBL 0201
80	CONTINUE	DBL 0202
	C ASSEMBLE DAMAGED HOLE (WITHOUT RING)	DBL 0203
85	RO=RI*((1.0+PI/12.0)*4)	DBL 0204
	CALL HOLEL(COORD,THK,S,RO,RHOLE,IHOLE,B)	DBL 0205
	KT1=NCON	DBL 0206
	CALL ASMSUB(IDM,RHOLE,IHOLE,RSS,ISS)	DBL 0207
	DO 86 I=1,2	DBL 0208
86	ISAVE1(I)=ISZ(I)	DBL 0209
	DO 87 I=1,6	DBL 0210
	ISAVE2(I)=IBEGIN(I)	DBL 0211
87	ISAVE3(I)=IEND(I)	DBL 0212
	CNODE=KT1	DBL 0213
	KT1=KT2	DBL 0214
	CALL LUG(WIDTH,LENGTH,NELW,THK,THK,C,NSZHL,RHOLE,IHOLE)	DBL 0215

```

      KT1=CNODE
      DO 88 I=1,2
      88  ISZ(I)=ISAVE1(I)
      DO 89 I=1,6
      89  IBEGIN(I)=ISAVE2(I)
      IEND(I)=ISAVE3(I)
      C ASSEMBLE LUG SUBSTRUCTURE
      CALL ASMSUB(NH2*5,RHOLE,IHOLE,RSS,ISS)
      IMASTR=IBEGIN(5)-1
      C CONSTRAIN NODES ORIGINALLY ASSIGNED TO HOLE CENTERS
      CNODE=100*NHOLES+2
      NCON=NMBCRN+1
      DO 92 NROW=1,2
      DO 90 N=1,NHOLES
      90  ISS(NCON)=CNODE
      ISS(NCON+1)=CNODE-1
      NCON=NCON+2
      90  CNODE=CNODE-4
      CNODE=112*NHOLES+12
      92  CONTINUE
      C CONSTRAIN ALL DOFS WHICH WERE ORIGINALLY ASSIGNED TO DAMAGED HOLE AND
      C WHICH WERE NOT USED ON BOTTOM EDGE
      MODEL=2*NDW+1
      DO 105 I=NODEL,48
      105  ISS(NCON)=CNSTRN(I)
      NCON=NCON+1
      NCON=NCON-1
      DO 106 I=1,NCON
      106  RSS(IMASTR+ISS(I))=0.0
      DTHETA=PI/24.0
      DTHT=PI/12.0
      PO=2.0/(RI*THK*PI)
      THETA=0.0
      DO 120 I=1,7
      120  SS1=SIN(THETA-DTHETA)
      SS2=SIN(THETA+DTHETA)

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DBL 0216
DBL 0217
DBL 0218
DBL 0219
DBL 0220
DBL 0221
DBL 0222
DBL 0223
DBL 0224
DBL 0225
DBL 0226
DBL 0227
DBL 0228
DBL 0229
DBL 0230
DBL 0231
DBL 0232
DBL 0233
DBL 0234
DBL 0235
DBL 0236
DBL 0237
DBL 0238
DBL 0239
DBL 0240
DBL 0241
DBL 0242
DBL 0243
DBL 0244
DBL 0245
DBL 0246
DBL 0247
DBL 0248
DBL 0249
DBL 0250
DBL 0251

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IF( I .EQ. 1 ) SS1=0.0
IF( I .EQ. 13 ) SS2=0.0
PNODE=PO*THK*DTHTA*(SS2+SS1)
IF( KTI .EQ. KW ) GO TO 110
WRITE(KW,6004) I,PNODE
6004 FORMAT(41H0CONSISTENT RR NODAL FORCE; GENERAL NODE ,I3,28H SCALEDDBL
@ P (XBEARING FORCE)=,E12.5)
110 SCALE(2,I)=PNODE*SIN(THETA)
SCALE(1,I)=PNODE*COS(THETA)
IF (KTI .EQ. KW ) GO TO 120
WRITE(KW,6005) I,(SCALE(J,I),J=1,2)
6005 FORMAT(21H0SCALE FACTORS; NODE ,I3,9H X SCALE=,E12.5,11H Y SCALEDDBL
@=,E12.5)
120 THETA=THETA+DTHT
DO 125 I=8,13
IMASTR=14-I
DO 125 J=1,2
125 SCALE(J,I)=SCALE(J,IMASTR)
DO 126 I=8,13
126 SCALE(1,I)=-SCALE(1,I)
SCALE(1,7)=0.0
C COSINE LOADING IN ALL BUT DAMAGED HOLE IS SCALED UP BY BFORCE(I) FOR
C HOLE NUMBER I
MODEL=7
IMASTR=IBEGIN(5)-1
DO 140 N=1,NH2
IF( N .EQ. IDM ) GO TO 140
DO 130 I=1,13
DO 130 J=1,2
RSS(IMASTR+MODEL)=SCALE(J,I)*BFORCE(N)
130 MODEL=MODEL+1
140 MODEL=N*48+7
145 CALL BCON(RSS,ISS)
C CONDENSE OUT ALL DOFS EXCEPT THOSE IN DAMAGED HOLE
I=1
CALL STACON(I,NIDSS,RSS,ISS)

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DBL 0252
 DBL 0253
 DBL 0254
 DBL 0255
 DBL 0256
 DBL 0257
 DBL 0258
 DBL 0259
 DBL 0260
 DBL 0261
 DBL 0262
 DBL 0263
 DBL 0264
 DBL 0265
 DBL 0266
 DBL 0267
 DBL 0268
 DBL 0269
 DBL 0270
 DBL 0271
 DBL 0272
 DBL 0273
 DBL 0274
 DBL 0275
 DBL 0276
 DBL 0277
 DBL 0278
 DBL 0279
 DBL 0280
 DBL 0281
 DBL 0282
 DBL 0283
 DBL 0284
 DBL 0285
 DBL 0286
 DBL 0287

DO 150 I=1,6		DBL 0288
150 IBGSS(I)=IBEGIN(I)		DBL 0289
NETSS=NET		DBL 0290
NDTSS=NDT		DBL 0291
NID=NIDSS		DBL 0292
IF (KT1.EQ. KW) GO TO 160		DBL 0293
WRITE(KW,6006)		DBL 0294
6006 FORMAT(1H0,61X,8HEXIT DBL)		DBL 0295
160 RETURN		DBL 0296
170 WRITE(KW,6007) RI,CLSPC		DBL 0297
6007 FORMAT(56H0*****PROGRAM INTERRUPT INITIATED BY SUBROUTINE DBL *****DBL		DBL 0298
@,/,27H USER SPECIFIED DIMENSIONS:/,10X,13H HOLE RADIUS=,E12.5,/,DBL		DBL 0299
@10X,30H CENTER LINE SPACING OF HOLES=,E12.5,/,87H SUCH DIMENSIONSDBL		DBL 0300
@ WILL CAUSE UNACCEPTABLE PROBLEMS WITH HOLE ELEMENT AND MUST BE ALDBL		DBL 0301
@TERED,/,21H RECOMMENDED CHANGES:,//)		DBL 0302
CLSPC=8.0*PI		DBL 0303
WRITE(KW,6008) WIDTH,CLSPC		DBL 0304
6008 FORMAT(33H LET RI BE LESS THAN OR EQUAL TO ,E12.5,56H OR LET CEN		DBL 0305
@R LINE SPACING BE GREATER THAN OR EQUAL TO ,E12.5)		DBL 0306
GO TO 190		DBL 0307
180 WRITE(KW,6007) RI,CLSPC		DBL 0308
CLSPC=12.0*PI		DBL 0309
WRITE(KW,6009) WIDTH,CLSPC		DBL 0310
6009 FORMAT(36H LET RI BE GREATER THAN OR EQUAL TO ,E12.5,53H OR LET CEN		DBL 0311
@ENTER LINE SPACING BE LESS THAN OR EQUAL TO ,E12.5)		DBL 0312
190 WRITE(KW,6010)		DBL 0313
6010 FORMAT(51H0***** EXECUTION TERMINATED IN SUBROUTINE DBL *****)		DBL 0314
STOP		DBL 0315
END		DBL 0316