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TWO DIMENSIONAL LINEAR ELASTIC ANALYSIS OF FRACTURE SPECIMENS U--ETC(U)

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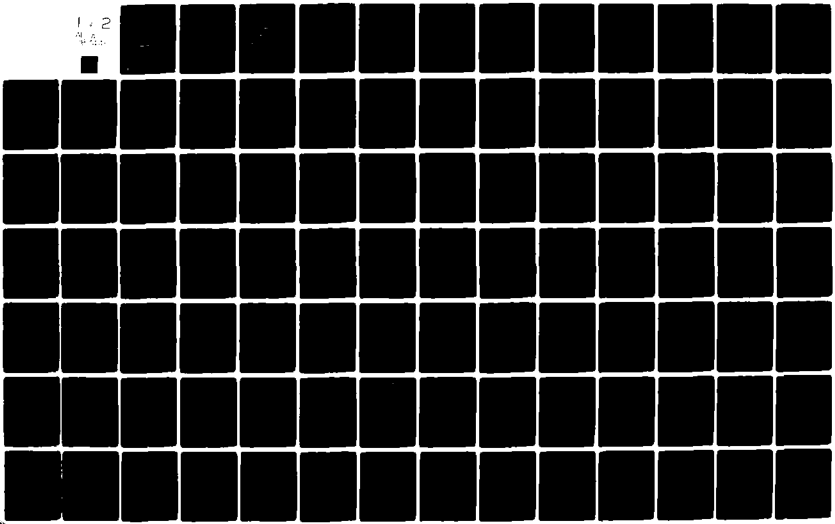
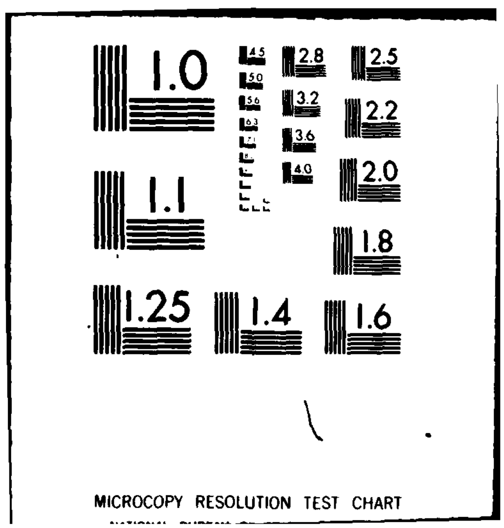
1 of 2

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1.25
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4.0
MICROCOPY RESOLUTION TEST CHART

AFWAL-TR-80-4008

TWO DIMENSIONAL LINEAR ELASTIC ANALYSIS OF FRACTURE SPECIMENS USER'S MANUAL OF A FINITE ELEMENT COMPUTER PROGRAM

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Project Engineer

FOR THE COMMANDER

NATHAN G. TUPPER
Chief, Metals Behavior Branch
Metals and Ceramics Division

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A Finite Element code for plane stress and plane strain linear elastic analysis of fatigue-crack-growth test specimen configurations was developed.
A user's manual for the above code along with user's manuals, for a mesh plotting program, and mesh generating programs for compact, three-point-bend, and ring specimen geometries is provided. Numerical examples for several specimen geometries are also included.

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FOREWORD

This report was prepared by the Research Applications Divison, Systems Research Laboratories, Inc., Dayton, OH, under Contract No. F33615-79-C-5025, "Mechanical Property Characterization and Modeling of Structural Materials". The contract was administered under the direction of the Air Force Materials Laboratory, Metals Behavior Branch (AFWAL/MLLN), by Dr. Theodore Nicholas, Project Manager. The research reported here was conducted by Jalees Ahmad and was performed during the period June 1979 to August 1979.

The author wishes to thank his colleagues Dr. N. Ashbaugh of Systems Research Laboratories, Inc., and Dr. T. Nicholas for their help, and Ms. Judy Paine for typing the present report.

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SECTION I
INTRODUCTION

Finite element method is now well established as one of the foremost numerical techniques for analyzing linear elastic crack problems. Among other advantages associated with the use of finite element method is the fact that complicated geometries and physical loading situations can be quite accurately modeled. Therefore, the method is useful in analyzing standard as well as nonstandard crack growth and fracture specimens which may be used in the laboratory.

A disadvantage of the method is that with even a slight change in the geometry of a given specimen, such as the crack length, a new finite element mesh is required. Since finite element mesh generation is usually a time consuming process, parametric studies involving any change in geometry are tedious. Using general purpose large finite element computer codes, such as NASTRAN or MARC, for such problems is an inefficient and expensive process. However, if special purpose finite element codes developed primarily for parametric studies of test specimens are used, the method can be employed economically and with improved efficiency.

The present report provides a user's guide for a special purpose finite element code developed primarily for two dimensional linear elastic analysis of test specimens. User's guides for some supporting computer programs, such as mesh generators for commonly used test specimens and for plotting a mesh, are also included. Precise instructions and a number of illustrative examples are provided to clarify the data preparation for executing the program.

It is expected that a user with only a basic knowledge of theory of elasticity and some acquaintance with FORTRAN language should be able to effectively employ the procedures included in this report.

SECTION II
PROGRAM HIGHLIGHTS

1. ASSUMPTIONS

1) Material is a homogeneous, isotropic, and linearly elastic solid.
2) Conditions of plane stress or plane strain exist.
3) Compared to the dimensions of the solid, displacements are small, and assumptions of linear theory of elasticity are valid.

2. METHOD OF SOLUTION

The numerical technique used by the program is based on displacement finite element formulation.

3. ELEMENT GEOMETRY

The element used in the present program is an eight node isoparametric quadrilateral[1] shown in Fig. 1. Some special and degenerate forms of this element are shown in Fig. 2. Element nodes are always numbered anticlockwise starting at any corner node. The four corner nodes are number (I), (I + 1), (I + 2), and (I + 3). The first intermediate node (I + 4) is always between corner nodes (I) and (I + 1). Other intermediate nodes are then numbered anticlockwise also.

4. MESH GENERATION

Mesh generation can be best explained by considering a simple example: consider the cantilever beam shown in Fig. 3. For simplicity let us decide to use only three elements. Fig. 4 shows some possible discretizations.

The mesh of Fig. 4a is most appropriate of all the other meshes shown. As a rule of thumb if the geometry of the problem so allows, curved, irregular and degenerate shapes should be avoided.

The node numbering should be such that the difference between any two node numbers belonging to the same element is kept as small as possible. This difference in Fig. 4a is 7 (=8 - 1). The above practice helps in reducing computational time.

Elements may be numbered in any arbitrary way. However it is a good practice to be systematic as in Fig. 4a. Size of each element, and the total number of elements in the mesh are decided depending upon the nature of a given problem. In general a finer mesh would provide more accurate results than a coarser mesh.

Mesh generation can be accomplished either by actually drawing the elements on a graph paper or by writing a mesh generation program. Usage of mesh generation programs for some specimen geometries is described in Appendix I.

5. TOPOLOGY

Complete topology of the mesh is described by individual element connectivities and X and Y coordinates of the nodal points with respect to any conveniently chosen X, Y coordinate system, as shown in the following example.

For the mesh shown in Fig. 4a the topology can be described as follows.

a. Nodal Coordinates

NODE	X	Y	NODE	X	Y	NODE	X	Y
1	4.0	0.5	7	3.50	1.0	13	1.50	1.5
2	4.0	1.0	8	3.50	1.5	14	1.25	0.5
3	4.0	1.5	9	2.50	0.5	15	1.25	1.5
4	3.75	0.5	10	2.50	1.5	16	1.00	0.5
5	3.75	1.5	11	1.50	0.5	17	1.00	1.0
6	3.50	0.5	12	1.50	1.0	18	1.00	1.5

b. <u>Connectivities</u>

Following the numbering convention described in 3, the element connectivites are as follows.

ELEM	I	I+1	I+2	I+3	I+4	I+5	I+6	I+7
1	1	3	8	6	2	5	7	4
2	8	13	11	6	10	12	9	7
3	16	11	13	18	14	12	15	17

Note that I can be chosen to be any corner node.

6. PLOTTING THE MESH

After generating a mesh and punching out the nodal coordinates and connectivities on data cards it is often desirable to check for any topographical errors. Perhaps the easiest way is to plot the final mesh. Usage of a mesh plotting computer program developed for this purpose is described in Appendix II.

7. SPECIFYING NODAL DISPLACEMENT AND FORCE BOUNDARY CONDITION

For simplicity the program (SRL01A) is designed to accept only zero displacement and non-zero force boundary conditions.

For the beam of Fig. 3 and using the mesh of Fig. 4a, we can specify zero X and Y displacement components at nodes 1, 2, and 3. Force of negative P can be specified in Y direction at node 18. The procedure for preparing boundary condition data is described in Section III.

8. SPECIFYING NON-ZERO STRESS AND PRESSURE ON ELEMENT SIDES

In problems where non-zero stress or pressure is to be specified (such as in crack problems with crack face pressure distribution), the pressure or stress distribution over any side of the element is given in polynomial form. Constant, linear, quadratic, and cubic distributions are permitted. The method for specifying these distributions is discussed in Section III.

9. ENFORCING CRACK TIP STRESS SINGULARITY

The elastic stress singularity at the crack tip is included by surrounding the crack tip by elements of the form shown in Fig. 2e. The collapsed nodes (I + 1), (I + 2), and (I + 5) are placed at the crack tip and the relative displacements among these nodes are forced to be zero. This is accomplished either by specifying the X and Y displacements of the above three nodes to be zero, or simply by assigning a single number to all three nodes in the nodal numbering of the mesh. Details of this method can be found in the paper by Barsoum.[2] The use of the above procedure is illustrated in Section IV.

SECTION III
DATA PREPARATION

1. USER'S GUIDE FOR SRL01A

In this section the method for inputting topology, material properties, and boundary conditions data for the solution of a given problem is described. Each data set refers to a specific information required by SRL01A for execution.

a. Data Set 1 (sizing card), Format (12I4), Number of cards = 1

Columns	Variable	Definition
1-4	NPRTYP	Problem Type (1 or 2).
5-8	NPOINT	Total number of nodes in the mesh.
9-12	NELEM	Total number of elements in the mesh.
13-16	NBOUN	Total number of nodes with displacement boundary condition.
17-20	NCONC	Total number of nodes with concentrated forces.
21-24	NFREE	Degrees of freedom per node (always give 2).
25-28	NYM	Number of different materials in the same problem.
29-32	NBAND	Expected band width.
33-36	IR	Number of nodes per element (always give 8).
37-40	NSTRSS	Stress computation indicator (0 or 1).
41-44	NCPOIN	Total number of corner nodes.
45-48	NQPTS	Total number of re-specified nodes.

Instructions

NPRTYP Give 1 for Plane Stress problem.
Give 2 for Plane Strain problem.

NPOINT Count and specify total number of nodes in the mesh (corner nodes + intermediate nodes).

NELEM Count and specify total number of elements in the mesh.

NBOUN Count and specify total number of nodes which are fixed in either one or both X and Y directions.

NCONC Count and specify total number of nodes which have concentrated applied forces in either one or both X and Y directions.

NYM In general each element in the mesh can be allowed to possess different elastic properties. If so, specify the total number of materials to be used. For uniform elastic properties for all elements give NYM equal to 1.

NBAND This is a sizing parameter found by the following formula.

NBAND = (Max. difference between any two nodes of an element + 1) × 2.

NSTRSS For crack problems where stress intensity factors are of interest give NSTRSS = 0. For other problems where element stress and strain components are required give NSTRSS = 1.

NCPOIN Total number of corner nodes (NPOINT - number of intermediate nodes) in the mesh.

NQPTS If NQPTS is given zero, the intermediate nodes are automatically placed at the middle of straight line distance between the adjoining corner nodes. For problems in which this arrangement needs to be altered, such as in crack problems using the element of Fig. 2e, the number of those intermediate nodes which have to be moved from the mid-position should be counted and specified as NQPTS.

b. Data Set 2 (Elastic Property Cards), Format (2F20.5), Number of Cards = NYM*

Columns	Variable	Definition
1-20	E1	Young's Modulus
21-40	P1	Poisson's Ratio

*See a. Section III.

c. Data Set 3 (Boundary Conditions), Format (4I4), Number of Cards = NBOUN*

Columns	Variable	Definition
1-4	NF(I)	Node with displacement boundary condition
5-8	NB(I,1)	Zero X-displacement indicator
9-12	NB(I,2)	Zero Y-displacement indicator

Instructions

NF(I) Give the number of a node whose X or Y or both displacements are fixed.

NB(I,1) Give 1 if X-displacement of node NF(I) is fixed. Give 0 if X-displacement of node NF(I) is not fixed.

NB(I,2) Same as NB(I,1) but for Y-displacement of node NF(I).

*See a. Section III.

d. Data Set 4 (Concentrated Loads), Format (I4,2F20·10), Number of Cards = NCONC*

Columns	Variable	Definition
1-4	NP	Node number of point with conc. load
5-24	U(NP×2-1)	Value of X-component of applied load
25-44	U(NP×2)	Value of Y-component of applied load

*See a. Section III.

e. <u>Data Set 5 (Corner Point Coordinates), Format (I4,2F10·5), Number of Cards = NCPOIN*</u>

Columns	Variable	Definitions
1-4	I	Corner node number**
5-14	X(I)	X-coordinate of I
15-24	Y(I)	Y-coordinate of I

*See a. Section III.

**For example in Fig. 4a points 1, 3, 6, 8, 11, 13, 16, and 18 are corner nodes (NCPOIN = 8).

f. <u>Data Set 6 (Element Connectivities), Format (9I4,F10·5,I4), Number of Cards = NELEM*</u>

Columns	Variable	Definitions
1-4	I	First corner node**
5-8	I+1	Second corner node
9-12	I+2	Third corner node
13-16	I+3	Fourth corner node
17-20	I+4	First intermediate node
21-24	I+5	Second intermediate node
25-28	I+6	Third intermediate node
29-32	I+7	Fourth intermediate node
33-36	NEP	Material property number
37-46	THICK	Element Thickness
47-50	NTYPEL	Applied pressure/stress indicator (0 or 1)

Instructions

NEP If a single material is used (NYM = 1 in Data Set 1), NEP is 1 for all elements.

NTYPEL If any side of an element (see Fig. 1) is subjected to applied pressure, for that element give NTYPEL as 1. For other elements NTYPEL is given 0.

*See a. Section III.

**Follow the numbering convention of Part 3. (Section II)

g. Data Set 7 (Crack Tip Node), Format (I4), Number of Cards = 1

Columns	Variable	Definition
1-4	NTIP	Node number of a node located at the crack tip*

*If there is no crack give zero.

h. Data Set 8 (Coordinate Modification), Format (I4,2F10·5), Number of Cards = NQPTS*

Columns	Variable	Definition
1-4	I	Node number of the point whose coordinates are to be modified
5-14	X(I)	X - coordinate of I
15-24	Y(I)	Y - coordinate of I

*See a. Section III.

i. Data Set 9 (Pressure Polynomial), Format (I4), Number of Cards = M*

Format (8F10·5), Number of Cards = M

Card 1

Columns	Variable	Definition
1-4	NSIDE	Side number of element on which pressure is applied (See Fig. 1)

Card 2

Columns	Variable	Definition
1-10	A_1	First coefficient of T_y traction polynomial**
11-20	A_2	Second coefficient of T_y traction polynomial
21-30	A_3	Third coefficient of T_y traction polynomial
31-40	A_4	Fourth coefficient of T_y traction polynomial
41-50	B_1	First coefficient of T_x traction polynomial
51-60	B_2	Second coefficient of T_x traction polynomial
61-70	B_3	Third coefficient of T_x traction polynomial
71-80	B_4	Fourth coefficient of T_x traction polynomial

This is an optional data set. Use only if one or more elements have NTYPEL = 1 (See f., Section III). If there are no such elements omit this data set altogether.

*M is the number of elements with NTYPEL = 1. For each such element there are two cards. The set of Card 1 and Card 2 has to be given for each such element. Give M such sets. The order of the sets is the same as the order of element cards in Data Set 6 which have NTYPEL = 1.

** $T_y = A_1 + A_2X + A_3X^2 + A_4X^3$

$T_x = B_1 + B_2Y + B_3Y^2 + B_4Y^3$

(Continued at top of next page)

T_x and T_y are the x- and y- traction components respectively, obtained by taking the vector dot product between the stress components and the outward unit normal on the surface.

j. Data Set 10 (K_I Computation Indicator), Format (I4), Number of Cards = 1*

Column	Number
4	1

*If NTIP=0 (see g. Section III), this card is omitted.

k. Data Set 11 (K_I Computation Point), Format (I4), Number of Cards = 1*

Columns	Variable	Definition
1-4	NKIC	Nodal point on the crack edge whose displacement is to be used for K_I calculation. NKIC should be approximately A/50.0 distance away from NTIP, where A denotes the crack length

*If NTIP=0)(see g. Section III), this card is omitted.

2. LIMITATIONS

For using the stored version of SRL01A the following limitations on the values of various variables should be observed.

$0 < \text{NPOINT} \leq 340$*

$0 < \text{NELEM} \leq 100$

$0 < \text{NBOUN} \leq 50$

$0 < \text{NBAND} \leq 100$

$0 < \text{NYM} \leq 5$

*For definitions of these variables see a. Section III.

SECTION IV

SOLUTION PROCEDURE

1. PROGRAM EXECUTION

The necessary control cards for executing the program with a single data set (one problem) or multiple data sets (many problems) are as follows.

First Card (Job Card), start at column 1.

AAA,CM300000,T100,IO100,STANY. M760328

AAA = Job identification number (eg. user's initials).
T100 = Execution time limit in seconds. This may be changed (eg. T60)
IO100 = Input-Output time limit in seconds. This may be changed.
M760328 = Example of user's code. Use appropriate account number.

Note: Put a period, then a blank after STANY.

Second Card (attach card), start at column 1.

ATTACH,LGO,SRL01A,ID=M760328.

SRL01A = Program name. For other programs described in appendices the program name is changed but other parameters remain identical. For executing SRL01A finite element program use the above card exactly the way it is shown.

Note the period after the ID value.

Third Card (load-go card), start at column 1.

LGO.

Fourth Card (end-of-record), this card is available at the computer center.

CARD SEQUENCE

The necessary control cards and data cards have to be arranged in the following sequence.

Job card

Attach Card

LGO.
.
.
.
.
LGO. } As many as number of problems to be solved.

End of record card
Data for first problem }

End of record card
Data for second problem }

.
.
.
.

End of record card
Data for the last problem }

End of job card.

SECTION V
NUMERICAL EXAMPLES

The purpose of providing solved numerical examples using the programs discussed in the present manual is to further clarify the data preparation and program execution described in previous sections.

1. EXAMPLE 1: SINGLE NOTCH SEMI-CIRCULAR SPECIMEN

In order to explain all the procedural details, let us start with the problem of a semi-circular ring containing a radial crack shown in Fig. 6. Due to axial symmetry about the X-axis only one half of the geometry is needed for analysis (Fig. 6b). To account for the other half, we need to specify Y-displacement (V) to be zero on the boundary indicated in Fig. 6b.

The purpose is to obtain nodal displacements and stress intensity factors (K_I) for various values of crack length (A), inner radius (R_i), and outer radius (R_o). We proceed in the following steps:

a. Step 1: Mesh Generation

As explained in Section 2, mesh generation can be accomplished either by hand or by using the computer. Let us use SRLC program of Appendix I to generate the mesh. The two data cards used were:

Card 1: Blank
Card 2: 0·5 1·0 2·0

The numbers in card 2 represent A, R_i, R_o, respectively.

The output of SRLC in the form of punched deck, and in print, was as follows:

```
      .50000    1.00000    2.00000
    1 185   52   17    1    2    1   70    8    0   57    5
          10000000.00000                          .30000
 105     0    1
 106     0    1
 107     0    1
 108     0    1
 109     0    1
 114     0    1
 123     0    1
 128     0    1
 137     0    1
 142     0    1
 151     0    1
 156     0    1
 165     0    1
 170     0    1
 179     0    1
 184     0    1
 185     1    1
  13                                            1.0000000000
   1      .00000     1.00000
   3      .00000     1.11250
   5      .00000     1.22500
   7      .00000     1.50000
   9      .00000     1.77500
  11      .00000     1.88750
  13      .00000     2.00000
  21     -.38268      .92388
  23     -.42574     1.02782
  25     -.46679     1.13175
  27     -.57403     1.38582
  29     -.67926     1.63989
  31     -.72231     1.74382
  33     -.76537     1.84776
  41     -.70711      .70711
  43     -.78606      .78606
  45     -.86621      .86621
  47    -1.06066     1.06066
  49    -1.29511     1.29511
  51    -1.33466     1.33466
  53    -1.41421     1.41421
  61     -.92388      .38268
  63    -1.02782      .42574
  65    -1.13175      .46679
```

67	-1.38582	.57403
69	-1.63969	.67926
71	-1.74382	.72231
73	-1.84776	.76537
81	-.99000	.11000
83	-1.11250	.11000
85	-1.22500	.11000
87	-1.50000	.11000
89	-1.77500	.11000
91	-1.88750	.11000
93	-1.98000	.11000
100	-1.00000	0.00000
102	-1.11250	0.00000
104	-1.22500	0.00000
105	-1.77500	0.00000
107	-1.88750	0.00000
109	-2.00000	0.00000
115	-1.33750	0.00000
117	-1.33750	.09000
119	-1.50000	.09000
121	-1.56250	.09000
123	-1.56250	0.00000
129	-1.39375	0.00000
131	-1.39375	.07500
133	-1.50000	.07500
135	-1.50625	.07500
137	-1.60625	0.00000
143	-1.45000	0.00000
145	-1.45000	.05000
147	-1.50000	.05000
149	-1.55000	.05000
151	-1.55000	0.00000
157	-1.48000	0.00000
159	-1.48000	.02000
161	-1.50000	.02000
163	-1.52000	.02000
165	-1.52000	0.00000
171	-1.49000	0.00000
173	-1.49293	.00707
175	-1.50000	.01000
177	-1.50707	.00707
179	-1.51000	0.00000
185	-1.50000	0.00000

3	23	21	1	15	22	14	2	1	1.00000
5	25	23	3	16	24	15	4	1	1.00000
7	27	25	5	17	26	16	6	1	1.00000
9	29	27	7	18	28	17	8	1	1.00000
11	31	29	9	19	30	18	10	1	1.00000
13	33	31	11	20	32	19	12	1	1.00000

23	43	41	21	35	42	34	22	1	1.00000
25	45	43	23	36	44	35	24	1	1.00000
27	47	45	25	37	46	36	26	1	1.00000
29	49	47	27	38	48	37	28	1	1.00000
31	51	49	29	39	50	38	30	1	1.00000
33	53	51	31	40	52	39	32	1	1.00000
43	63	61	41	55	62	54	42	1	1.00000
45	65	63	43	56	64	55	44	1	1.00000
47	67	65	45	57	66	56	46	1	1.00000
49	69	67	47	58	68	57	48	1	1.00000
51	71	69	49	59	70	58	50	1	1.00000
53	73	71	51	60	72	59	52	1	1.00000
63	83	81	61	75	82	74	62	1	1.00000
65	85	83	63	76	84	75	64	1	1.00000
67	87	85	65	77	86	76	66	1	1.00000
69	89	87	67	78	88	77	68	1	1.00000
71	91	89	69	79	90	78	70	1	1.00000
73	93	91	71	80	92	79	72	1	1.00000
81	83	102	100	82	95	101	94	1	1.00000
83	85	104	102	84	96	103	95	1	1.00000
89	91	107	105	90	98	106	97	1	1.00000
91	93	109	107	92	99	108	98	1	1.00000
85	117	115	104	111	116	110	96	1	1.00000
85	87	119	117	86	112	116	111	1	1.00000
87	89	121	119	88	113	120	112	1	1.00000
121	69	105	123	113	97	114	122	1	1.00000
117	131	129	115	125	130	124	116	1	1.00000
117	119	133	131	118	126	132	125	1	1.00000
119	121	135	133	120	127	134	126	1	1.00000
135	121	123	137	127	122	128	136	1	1.00000
131	145	143	129	139	144	138	130	1	1.00000
131	133	147	145	132	140	146	139	1	1.00000
133	135	149	147	134	141	148	140	1	1.00000
149	135	137	151	141	136	142	150	1	1.00000
145	159	157	143	153	158	152	144	1	1.00000
147	149	163	161	146	155	162	154	1	1.00000
145	147	161	159	146	154	160	153	1	1.00000
163	149	151	165	155	150	156	164	1	1.00000
159	173	171	157	167	172	166	158	1	1.00000
159	161	175	173	160	168	174	167	1	1.00000
161	163	177	175	162	169	176	168	1	1.00000
177	163	165	179	169	164	170	178	1	1.00000
173	165	185	171	181	185	180	172	1	1.00000
175	185	185	173	182	185	181	174	1	1.00000
177	165	185	175	183	185	182	176	1	1.00000
179	185	185	177	184	185	183	178	1	1.00000

185

180	-1.49750	0.00000
181	-1.49823	.00177
182	-1.50000	.00250
183	-1.50177	.00177
184	-1.50250	0.00000

1

171

The first line in the output gives the crack length and the inner and outer radii of the specimen. The rest of the computer print-out corresponds to the data sets described in Section III as follows.

Line 2	Data set 1
Line 3	Data set 2
Lines 4 to 20	Data set 3
Line 21	Data set 4
Lines 22 to 88	Data set 5
Lines 89 to 140	Data set 6
Line 141	Data set 7
Lines 142 to 146	Data set 8
Line 147	Data set 10
Line 148	Data set 11

Note that data set 9 is missing because no element side is subjected to applied pressure.

b. Step 2: Mesh Plotting

From the punched data deck of step 1, data sets 5 and 6 (coordinates and connectivities) were temporarily removed for use in the plotting program SRL11. In accordance with the description provided in Appendix II, the following data was supplied to SRL11.

```
6      185      52
[Nodal coordinates of data set 5 above]
[Blank card]
[Connectivities of data set 6 above]
1      20      1      C-SPEC
0.0    2.0    -2.0    -1.0    3.0    3.0    1.0    1.0
[Blank card]
End-of-record.
```

By executing SRL11, the plot shown in Fig. 7 was obtained. In Fig. 8 details of the fine mesh near the crack-tip are shown. Fig. 8 was obtained by supplying SRL11 with only those element connectivities which were to be plotted and by increasing the scales (XSCALE, YSCALE). The number of elements (52) in the first data card corresponds to the number of elements which are to be plotted.

c. Step 3: Executing SRL01A

Data sets 5 and 6 were placed back in their proper sequence in the punched data deck of Step 1 after removing the blank card which was inserted behind data set 5 for plotting purpose. SRL01A was then executed by using the following cards.

```
Job card
ATTACH,LGO,SRL01A,ID=M760328.
LGO.
End-of-record
[Data deck of Step 1]
End-of-job.
```

The output of SRL01A was as follows.

		X-COORD	Y-COORD	X-DISPL	Y-DISPL
NODE	1	0.00000	1.00000	-.5544338E-05	.1118594E-04
NODE	2	0.00000	1.05625	-.5948113E-05	.1118768E-04
NODE	3	0.00000	1.11250	-.6349219E-05	.1118936E-04
NODE	4	0.00000	1.16875	-.6749467E-05	.1119253E-04
NODE	5	0.00000	1.22500	-.7147688E-05	.1119793E-04
NODE	5	0.00000	1.36250	-.8119217E-05	.1123120E-04
NODE	7	0.00000	1.50000	-.9094780E-05	.1127892E-04
NODE	8	0.00000	1.63750	-.1009260E-04	.1136766E-04
NODE	9	0.00000	1.77500	-.1112865E-04	.1146366E-04
NODE	10	0.00000	1.83125	-.1155909E-04	.1151695E-04
NODE	11	0.00000	1.88750	-.1202275E-04	.1155984E-04
NODE	12	0.00000	1.94375	-.1249737E-04	.1162922E-04
NODE	13	0.00000	2.00000	-.1299287E-04	.1168731E-04
NODE	14	-.19134	.96194	-.5270607E-05	.9795948E-05
NODE	15	-.21287	1.07016	-.6053292E-05	.9638442E-05
NODE	16	-.23440	1.17838	-.6817126E-05	.9489123E-05
NODE	17	-.28702	1.44291	-.8657729E-05	.9141391E-05
NODE	18	-.33963	1.70745	-.1057126E-04	.8777334E-05
NODE	19	-.36116	1.81566	-.1138719E-04	.8614537E-05
NODE	20	-.38269	1.92388	-.1222090E-04	.8444207E-05
NODE	21	-.38268	.92388	-.5032954E-05	.8367473E-05
NODE	22	-.40421	.97585	-.5405743E-05	.8206768E-05
NODE	23	-.42574	1.02782	-.5772520E-05	.8050815E-05
NODE	24	-.44727	1.07979	-.6135354E-05	.7897451E-05
NODE	25	-.46879	1.13175	-.6434890E-05	.7746136E-05
NODE	26	-.52141	1.25879	-.7371502E-05	.7381353E-05
NODE	27	-.57403	1.38582	-.8231564E-05	.7015532E-05
NODE	28	-.62665	1.51286	-.9144595E-05	.6653324E-05
NODE	29	-.67926	1.63989	-.1014965E-04	.6284226E-05
NODE	30	-.70079	1.69186	-.1042245E-04	.6139021E-05
NODE	31	-.72231	1.74382	-.1079563E-04	.5931771E-05
NODE	32	-.74384	1.79579	-.1115402E-04	.5853098E-05
NODE	33	-.76537	1.84776	-.1152635E-04	.5715015E-05

NODE	34	-.54490	.81550	-.4347320E-05	.7140409E-05
NODE	35	-.60620	.90724	-.4978685E-05	.6698147E-05
NODE	36	-.66750	.99898	-.5598607E-05	.5275675E-05
NODE	37	-.81735	1.22324	-.7104505E-05	.5276399E-05
NODE	38	-.96719	1.44750	-.8629314E-05	.4286733E-05
NODE	39	-1.02849	1.53924	-.9262270E-05	.3880869E-05
NODE	40	-1.08979	1.63099	-.9898777E-05	.3468148E-05
NODE	41	-.70711	.70711	-.3721765E-05	.5917215E-05
NODE	42	-.74689	.74689	-.3975645E-05	.5644835E-05
NODE	43	-.78666	.78666	-.4229[illegible]9E-05	.5390267E-05
NODE	44	-.82644	.82644	-.4482848E-05	.5119021E-05
NODE	45	-.86621	.86621	-.4738108E-05	.4861396E-05
NODE	46	-.96344	.96344	-.5358464E-05	.4241957E-05
NODE	47	-1.06966	1.06966	-.5985071E-05	.3625894E-05
NODE	48	-1.15789	1.15789	-.6615015E-05	.3012551E-05
NODE	49	-1.25511	1.25511	-.7253475E-05	.2339539E-05
NODE	50	-1.29489	1.29489	-.7517813E-05	.2145118E-05
NODE	51	-1.33466	1.33466	-.7782252E-05	.1890455E-05
NODE	52	-1.37444	1.37444	-.8048730E-05	.1634020E-05
NODE	53	-1.41421	1.41421	-.9315603E-05	.1377559E-05
NODE	54	-.81550	.54490	-.2810917E-05	.5075851E-05
NODE	55	-.90724	.60620	-.3164694E-05	.4532887E-05
NODE	56	-.99898	.66750	-.3527007E-05	.3935580E-05
NODE	57	-1.22324	.81735	-.4419212E-05	.2569491E-05
NODE	58	-1.44750	.96719	-.5333919E-05	.1239784E-05
NODE	59	-1.53924	1.02849	-.5720674E-05	.5936101E-06
NODE	60	-1.63099	1.08979	-.5112210E-05	.1434356E-06
NODE	61	-.92338	.38268	-.1953229E-05	.4282656E-05
NODE	62	-.97585	.40421	-.2065298E-05	.3978761E-05
NODE	63	-1.02732	.42574	-.2193547E-05	.3657129E-05
NODE	64	-1.07979	.44727	-.2300172E-05	.3355120E-05
NODE	65	-1.13175	.46679	-.2414868E-05	.3042143E-05
NODE	66	-1.25379	.52141	-.2699245E-05	.2277046E-05
NODE	67	-1.38582	.57403	-.2964792E-05	.1558249E-05
NODE	68	-1.51286	.62665	-.3238999E-05	.8839430E-06

NODE	69	-1.63989	.67926	-.3523913E-05	.2124735E-06
NODE	70	-1.69186	.70079	-.3648872E-05	-.6297139E-07
NODE	71	-1.74382	.72231	-.3781216E-05	-.3446869E-06
NODE	72	-1.79579	.74384	-.3917469E-05	-.6357278E-06
NODE	73	-1.84776	.76537	-.4059693E-05	-.9394119E-06
NODE	74	-.95694	.24634	-.1243069E-05	.4022322E-05
NODE	75	-1.07016	.26787	-.1359336E-05	.3370069E-05
NODE	76	-1.17836	.28940	-.1492764E-05	.2699293E-05
NODE	77	-1.44291	.34202	-.1742107E-05	.1111459E-05
NODE	78	-1.70745	.39463	-.1668544E-05	-.6551651E-07
NODE	79	-1.81566	.41616	-.1995661E-05	-.4755020E-06
NODE	80	-1.91388	.43769	-.2135318E-05	-.8891806E-06
NODE	81	-.99000	.11000	-.4975022E-06	.3813443E-05
NODE	82	-1.05125	.11000	-.4935758E-06	.3462731E-05
NODE	83	-1.11250	.11000	-.5058973E-06	.3096021E-05
NODE	84	-1.16875	.11000	-.5158816E-06	.2756698E-05
NODE	85	-1.22500	.11000	-.5322482E-06	.2409334E-05
NODE	86	-1.36250	.11000	-.6177528E-06	.1455955E-05
NODE	87	-1.50000	.11000	-.6631824E-06	.4940997E-06
NODE	88	-1.63750	.11000	-.6817707E-06	.5018363E-07
NODE	89	-1.77500	.11000	-.7485031E-06	-.1070264E-06
NODE	90	-1.83125	.11000	-.7835321E-06	-.1629965E-06
NODE	91	-1.88750	.11000	-.8224348E-06	-.2179635E-06
NODE	92	-1.93375	.11000	-.8503496E-06	-.2551877E-06
NODE	93	-1.98000	.11000	-.8833524E-06	-.2957478E-06
NODE	94	-.99500	.05500	-.1850719E-06	.3785738E-05
NODE	95	-1.11250	.05500	-.1885385E-06	.3098171E-05
NODE	96	-1.22500	.05500	-.2098445E-06	.2407389E-05
NODE	97	-1.77500	.05500	-.6590814E-06	-.5776023E-07
NODE	98	-1.88750	.05500	-.7525147E-06	-.1129885E-06
NODE	99	-1.99000	.05500	-.8346813E-06	-.1371992E-06
NODE	100	-1.00000	0.00000	.1339709E-06	.3759390E-05
NODE	101	-1.05625	0.00000	.1350983E-06	.3430741E-05
NODE	102	-1.11250	0.00000	.1358062E-06	.3099471E-05
NODE	103	-1.16375	0.00000	.1364407E-06	.2750506E-05

NODE 104	-1.22500	0.00000	.1346449E-06	.2406818E-05
NODE 105	-1.77500	0.00000	-.6249694E-06	0.
NODE 106	-1.83125	0.00000	-.6800813E-06	0.
NODE 107	-1.88750	0.00000	-.7323205E-06	0.
NODE 108	-1.94375	0.00000	-.7813323E-06	0.
NODE 109	-2.00000	0.00000	-.8233226E-06	0.
NODE 110	-1.28125	0.00000	.1262503E-06	.2037022E-05
NODE 111	-1.28125	.10000	-.5084188E-06	.2022918E-05
NODE 112	-1.50000	.10000	-.6222175E-06	.4746654E-06
NODE 113	-1.71875	.10000	-.5910433E-06	-.6483172E-07
NODE 114	-1.71875	0.00000	-.5635618E-06	0.
NODE 115	-1.33750	0.00000	.1023429E-06	.1648727E-05
NODE 116	-1.33750	.04500	-.2015904E-06	.1641405E-05
NODE 117	-1.33750	.09000	-.4864502E-06	.1631956E-05
NODE 118	-1.41875	.09000	-.5407370E-06	.1051833E-05
NODE 119	-1.50000	.09000	-.5835091E-06	.4439621E-06
NODE 120	-1.58125	.09000	-.5639249E-06	.1613830E-06
NODE 121	-1.66250	.09000	-.5260260E-06	-.5145343E-08
NODE 122	-1.66250	.04500	-.5234682E-06	-.5417180E-08
NODE 123	-1.66250	0.00000	-.4857085E-06	0.
NODE 124	-1.36563	0.00000	.8768525E-07	.1451606E-05
NODE 125	-1.36563	.08250	-.4539821E-06	.1435194E-05
NODE 126	-1.50000	.08250	-.5514809E-06	.4335251E-06
NODE 127	-1.63438	.08250	-.5817649E-06	.3519755E-07
NODE 128	-1.63438	0.00000	-.4423072E-06	0.
NODE 129	-1.39375	0.00000	.7014905E-07	.1249598E-05
NODE 130	-1.39375	.03750	-.1970043E-06	.1239674E-05
NODE 131	-1.39375	.07500	-.4377446E-06	.1232279E-05
NODE 132	-1.44688	.07500	-.4630560E-06	.8320225E-06
NODE 133	-1.50000	.07500	-.5186938E-06	.4161794E-06
NODE 134	-1.55313	.07500	-.5153501E-06	.2033534E-06
NODE 135	-1.60625	.07500	-.5374187E-06	.7555311E-07
NODE 136	-1.60625	.03750	-.4339444E-06	.3214798E-07
NODE 137	-1.60625	0.00000	-.3940857E-06	0.
NODE 138	-1.42188	0.00000	.5275899E-07	.1036343E-05

NODE 139	-1.42188	.06250	-.3937640E-06	.1022217E-05
NODE 140	-1.50000	.06250	-.4621973E-06	.3845084E-06
NODE 141	-1.57813	.06250	-.4738275E-06	.1058497E-06
NODE 142	-1.57813	0.00000	-.3334037E-06	0.
NODE 143	-1.45000	0.00000	.3204350E-07	.8025578E-06
NODE 144	-1.45000	.02500	-.1789004E-06	.7944949E-06
NODE 145	-1.45000	.05000	-.3511034E-06	.7915381E-06
NODE 146	-1.47500	.05000	-.3846019E-06	.5720609E-06
NODE 147	-1.50000	.05000	-.4022133E-06	.3536075E-06
NODE 148	-1.52500	.05000	-.4014355E-06	.2131164E-06
NODE 149	-1.55000	.05000	-.4083015E-06	.1340808E-06
NODE 150	-1.55000	.02500	-.3158761E-06	.5977093E-07
NODE 151	-1.55000	0.00000	-.2722674E-06	0.
NODE 152	-1.46500	0.00000	.2230850E-07	.6598500E-06
NODE 153	-1.46500	.03500	-.2603197E-06	.5524858E-06
NODE 154	-1.50000	.03500	-.3255230E-06	.2957838E-06
NODE 155	-1.53500	.03500	-.3332949E-06	.1158792E-06
NODE 156	-1.53500	0.00000	-.2285842E-06	0.
NODE 157	-1.48000	0.00000	.1190240E-07	.4926211E-06
NODE 158	-1.48000	.01000	-.1078241E-06	.4873054E-06
NODE 159	-1.48000	.02000	-.2016013E-06	.4860412E-06
NODE 160	-1.49000	.02000	-.2261649E-06	.3573232E-06
NODE 161	-1.50000	.02000	-.2385596E-06	.2271512E-06
NODE 162	-1.51000	.02000	-.2393529E-06	.1380161E-06
NODE 163	-1.52000	.02000	-.2461589E-06	.9224067E-07
NODE 164	-1.52000	.01000	-.1982231E-06	.4203264E-07
NODE 165	-1.52000	0.00000	-.1726745E-06	0.
NODE 166	-1.48500	0.00000	.8714181E-08	.4232380E-06
NODE 167	-1.48647	.01354	-.1636409E-06	.3978084E-06
NODE 168	-1.50000	.01500	-.2035248E-06	.1970502E-06
NODE 169	-1.51354	.01354	-.2003819E-06	.7619635E-07
NODE 170	-1.51500	0.00000	-.1493966E-06	0.
NODE 171	-1.49000	0.00000	.5911950E-08	.3444641E-06
NODE 172	-1.49147	.00354	-.5884843E-07	.3158471E-06
NODE 173	-1.49293	.00707	-.1155102E-05	.2861770E-05

NODE 174	-1.49647	.00654	-.1458704E-05	.2187675E-06
NODE 175	-1.50000	.01096	-.1646212E-06	.1620306E-06
NODE 176	-1.50354	.00354	-.1525125E-05	.9940581E-07
NODE 177	-1.50707	.00707	-.1430884E-06	.5661158E-07
NODE 178	-1.50854	.01336	-.1238405E-06	.2333771E-07
NODE 179	-1.51039	[illegible]	-.1222494E-06	0.
NODE 180	-1.43750	[illegible]	.1579433E-08	.1739906E-06
NODE 181	-1.49823	.00177	-.5795286E-07	.1429146E-06
NODE 182	-1.50000	.00250	-.8092338E-07	.8122370E-07
NODE 183	-1.50177	.00177	-.7642881E-07	.2894592E-07
NODE 184	-1.50250	0.00000	-.6011966E-07	0.
NODE 185	-1.50000	0.00000	0.	0.

THE CRACK TIP IS AT NODE 185

*** STRESS INTENSITY FACTORS ***

USING THE Y-DISPL OF NODE 171 KI= 21.08609

d. Step 4: Interpretation of Results

The K_I value for the problem is computed by the program and is given at the end of the output. Displacement values at various locations, such as crack mouth opening displacement (node 100) and load point displacement (node 13) can be read directly by identifying the proper node number on the mesh. It should be noted that the actual crack mouth opening displacement and total load line displacement in the present case will be twice the Y-displacement of nodes 100 and 13, respectively. The results are:

$K_I = 21 \cdot 58609$ psi$\sqrt{in}$, Load Point Displacement = $233 \cdot 74620 \times 10^{-7}$ in.
Crack Mouth Opening Displacement = $75 \cdot 1878 \times 10^{-7}$ in.

e. Remarks

```
AAA,CM7000,T100,IO100,STANY. M-----
ATTACH,TAPE8,SRLC1,ID=M760328.
ATTACH,LGO,SRLC,ID=M760328.
LGO.
End-of-record
3  (Total number of cases minus 1)
0.2     1.0     2.0
0.3     1.0     2.0
0.4     1.0     4.0
0.5     1.0     4.0
End-of-job.
```

The above set-up will produce data for crack lengths 0.2, 0.3, 0.4, and 0.5 for $R_i = 1.0$ and $R_o = 2.0$. The job set-up for multiple runs using SRL01A is described in Section IV.

Note that the last four elements are as shown in Fig. 2e. Nodes 180, 181, 182, 183, and 184 are located at quarter points of the element sides. This necessitates the specification of the coordinates of these points in data set 8 (Section III). The purpose of this particular procedure is to model the proper stress singularity or the crack tip as mentioned in Section II.

2. EXAMPLE 2: DOUBLE NOTCH RING TENSION SPECIMEN

Consider a double notch circular ring (Fig. 9) under diametral tension. Due to symmetry about X and Y axes only one quarter of the ring needs to be considered for analysis. In fact by changing only the boundary conditions the same mesh as of Example 1 (Fig. 7) can be used. This is accomplished simply by changing the data sets 1, 3, and 4 of Example 1. The following computer print-out shows the changes in the above data sets.

```
  1 185  52  30   1   2   1  70   8   0  67   5
    10000000.00000                 .30000
105   0   1      0.000000000000        0.000000000000
106   0   1      0.000000000000        0.000000000000
107   0   1      0.000000000000        0.000000000000
108   0   1      0.000000000000        0.000000000000
109   0   1      0.000000000000        0.000000000000
114   0   1      0.000000000000        0.000000000000
123   0   1      0.000000000000        0.000000000000
128   0   1      0.000000000000        0.000000000000
137   0   1      0.000000000000        0.000000000000
142   0   1      0.000000000000        0.000000000000
151   0   1      0.000000000000        0.000000000000
156   0   1      0.000000000000        0.000000000000
165   0   1      0.000000000000        0.000000000000
170   0   1      0.000000000000        0.000000000000
179   0   1      0.000000000000        0.000000000000
184   0   1      0.000000000000        0.000000000000
185   0   1      0.000000000000        0.000000000000
  1   1   0      0.000000000000        0.000000000000
  2   1   0      0.000000000000        0.000000000000
  3   1   0      0.000000000000        0.000000000000
  4   1   0      0.000000000000        0.000000000000
  5   1   0      0.000000000000        0.000000000000
  6   1   0      0.000000000000        0.000000000000
  7   1   0      0.000000000000        0.000000000000
  8   1   0      0.000000000000        0.000000000000
  9   1   0      0.000000000000        0.000000000000
 10   1   0      0.000000000000        0.000000000000
 11   1   0      0.000000000000        0.000000000000
 12   1   0      0.000000000000        0.000000000000
 13   1   0      0.000000000000        0.000000000000
  1         0.0000000000         1.0000000000
```

Note that in data set 1 the number of boundary conditions (NBOUN) has been changed from 17 to 30. In data set 3, thirteen more boundary conditions have been added and the boundary condition of the crack tip has been changed. In data set 4, the load is now applied at node 1. Also, since the applied load is 1·0 lbs, the resulting values for displacements and K_I should correspond to a 2·0 lbs load on the actual ring.

The rest of the solution procedure remains identical to that of Example 1. The computer print-out of the results obtained by SRL01A is shown on the following pages.

		X-COORD	Y-COORD	X-DISPL	Y-DISPL
NODE	1	[illegible]	1.[illegible]	0.	.2234021E-05
NODE	2	[illegible]	1.05625	0.	.2173520E-05
NODE	3	[illegible]	1.1125	0.	.2110441E-05
NODE	4	[illegible]	1.16875	0.	.2079696E-05
NODE	5	[illegible]	1.225	0.	.2032665E-05
NODE	6	[illegible]	1.3625	0.	.1976163E-05
NODE	7	[illegible]	1.5[illegible]	0.	.1929413E-05
NODE	8	[illegible]	1.6[illegible]75	0.	.1995277E-05
NODE	9	[illegible]	1.775[illegible]	0.	.1866730E-05
NODE	10	[illegible]	1.[illegible]3.25	0.	.1855617E-05
NODE	11	[illegible]	1.8875	0.	.1845491E-05
NODE	12	[illegible]	1.94375	0.	.1835428E-05
NODE	13	[illegible]	2.[illegible]	0.	.1825764E-05
NODE	14	-.19134	.96194	.2261237E-06	.1916[illegible]E-05
NODE	15	-.21287	1.[illegible]16	.1114359E-06	.1921691E-05
NODE	16	-.2344[illegible]	1.17838	.5742147E-07	.1903968E-05
NODE	17	-.29702	1.4429[illegible]	-.3007154E-07	.1833956E-05
NODE	18	-.3396[illegible]	1.7[illegible]745	-.1171539E-06	.1765524E-05
NODE	19	-.36116	1.81566	-.1589546E-06	.1738[illegible]41E-05
NODE	20	-.38269	1.92388	-.2[illegible]43859E-06	.1709916E-05
NODE	21	-.38768	.92388	.3660[illegible]E-06	.1752153E-05
NODE	22	-.40421	.97565	.3098982E-06	.172[illegible]E-05
NODE	23	-.42574	1.[illegible]7702	.2654777E-06	.1704435E-05
NODE	24	-.44727	1.[illegible]7379	.2152447E-06	.1687646E-05
NODE	25	-.46879	1.1[illegible]75	.1710645E-06	.1665745E-05
NODE	26	-.52141	1.25979	.7946692E-07	.1627[illegible]E-05
NODE	27	-.574[illegible]	1.355[illegible]	-.1343433E-0[illegible]	.1579378E-05
NODE	28	-.62665	1.51[illegible]	-.8371[illegible]E-07	.1528663E-05
NODE	29	-.67326	1.63389	-.17[illegible]153E-06	.1473923E-05
NODE	30	-.7[illegible]79	1.69166	-.2[illegible]7E-06	.145[illegible]E-05
NODE	31	-.7223[illegible]	1.74[illegible]	-.248[illegible]E-06	.1425611E-05
NODE	32	-.74384	1.79579	-.2927536E-06	.1399657E-05
NODE	33	-.76[illegible]	1.84776	-.[illegible]374[illegible]E-06	.1372585E-05

NODE	34	-.54498	.81551	.5702314E-06	.1572224E-05
NODE	35	-.61624	.91724	.4528851E-06	.1503216E-05
NODE	36	-.66751	.99098	.3545617E-06	.1438675E-05
NODE	37	-.81773	1.07364	.1478868E-06	.1286848E-05
NODE	38	-.86719	1.14475	-.5216592E-07	.1125017E-05
NODE	39	-1.02849	1.50924	-.1413646E-06	.1053319E-05
NODE	40	-1.03979	1.55190	-.2332262E-06	.9786631E-06
NODE	41	-.70711	.70711	.7439982E-06	.1375926E-05
NODE	42	-.74583	.74589	.6916583E-06	.1322653E-05
NODE	43	-.78666	.78666	.6422134E-06	.1273215E-05
NODE	44	-.82644	.82644	.5949472E-06	.1225238E-05
NODE	45	-.86621	.86621	.5492039E-06	.1179457E-05
NODE	46	-.96344	.96344	.4461167E-06	.1068375E-05
NODE	47	-1.06366	1.06366	.3460810E-06	.9578425E-06
NODE	48	-1.15789	1.15789	.2454439E-06	.8453176E-06
NODE	49	-1.25511	1.25511	.1411936E-06	.7285085E-06
NODE	50	-1.29489	1.29489	.9627915E-07	.6787580E-06
NODE	51	-1.33466	1.33466	.5058490E-07	.6281862E-06
NODE	52	-1.37444	1.37444	.1864493E-08	.5747244E-06
NODE	53	-1.41421	1.41421	-.4701[illegible]E-07	.5205155E-06
NODE	54	-.81551	.54481	.9752014E-06	.1224518E-05
NODE	55	-.91724	.61620	.8336652E-06	.1109852E-05
NODE	56	-.99898	.66751	.6146218E-06	.9638876E-06
NODE	57	-1.22324	.81775	.6545889E-06	.7079791E-06
NODE	58	-1.44750	.96730	.4904375E-06	.4342413E-06
NODE	59	-1.53324	1.02849	.4173173E-06	.3177161E-06
NODE	60	-1.63099	1.09979	.3425451E-06	.1983768E-06
NODE	61	-.92788	.72269	.1193359E-05	.1063598E-05
NODE	62	-.97565	.44420	.1142149E-05	.9928156E-06
NODE	63	-1.02782	.43576	.1165158E-05	.9217509E-06
NODE	64	-1.07979	.44727	.1132735E-05	.8517434E-06
NODE	65	-1.17175	.46671	.1054917E-05	.7820036E-06
NODE	66	-1.25879	.52141	.1027438E-05	.6117551E-06
NODE	67	-1.35582	.57447	.9775661E-06	.4535082E-06

NODE	68	-1.51286	.62665	.9262912E-06	.3041381E-06
NODE	69	-1.63969	.67926	.8723918E-06	.1529318E-06
NODE	70	-1.63166	.7[illegible]279	.8477[illegible]3E-06	.9330772E-07
NODE	71	-1.74[illegible]	.72231	.82[illegible]8869E-06	.2567732E-07
NODE	72	-1.79579	.74384	.7921498E-06	-.4311664E-07
NODE	73	-1.34776	.76537	.7614023E-06	-.1155702E-06
NODE	74	-.95694	.24674	.1367828E-05	.1011275E-05
NODE	75	-1.[illegible]	.26707	.1339927E-05	.8547465E-06
NODE	76	-1.17836	.28940	.1385514E-05	.6969907E-06
NODE	77	-1.44291	.34262	.126[illegible]165E-05	.3219202E-06
NODE	78	-1.72745	.39463	.1244793E-05	.4297386E-07
NODE	79	-1.61566	.41616	.1226397E-05	-.5427338E-07
NODE	80	-1.91784	.43769	.1198243E-05	-.1523354E-06
NODE	81	-.99[illegible]	.1[illegible]	.1552984E-05	.9642689E-06
NODE	82	-1.05125	.11[illegible]	.1552786E-05	.8787259E-06
NODE	83	-1.11250	.11950	.1551827E-05	.7906941E-06
NODE	84	-1.16375	.11[illegible]	.1550331E-05	.7097190E-06
NODE	85	-1.225[illegible]	.11[illegible]	.154733[illegible]E-05	.6268411E-06
NODE	86	-1.3625[illegible]	.11[illegible]	.1539135E-05	.3912666E-06
NODE	87	-1.5[illegible]	.11[illegible]	.1524862E-05	.1437758E-06
NODE	88	-1.63750	.11[illegible]	.152910[illegible]2E-05	.3046692E-07
NODE	89	-1.775[illegible]	.11[illegible]	.152126[illegible]4E-05	-.1022938E-07
NODE	90	-1.83125	.11[illegible]	.1515460E-05	-.2414584E-07
NODE	91	-1.89750	.11[illegible]	.15[illegible]8575E-05	-.3809343E-07
NODE	92	-1.93375	.11[illegible]	.15[illegible]349[illegible]E-05	-.4953911E-07
NODE	93	-1.96[illegible]	.11[illegible]	.1497116E-05	-.6270463E-07
NODE	94	-.99[illegible]	.155[illegible]	.16300[illegible]E-05	.9576720E-06
NODE	95	-1.11250	.155[illegible]	.1629843E-05	.7911881E-06
NODE	96	-1.2250[illegible]	.1551[illegible]	.1627277E-05	.6255933E-06
NODE	97	-1.775[illegible]	.155[illegible]	.1543351E-05	-.6209531E-08
NODE	98	-1.8875	.155[illegible]	.1526466E-05	-.2004135E-07
NODE	99	-1.99[illegible]	.155[illegible]	.151[illegible]413E-05	-.2940123E-07
NODE	1[illegible]	-1.[illegible]	.[illegible]	.17[illegible]798[illegible]E-05	.9511695E-06
NODE	[illegible]	-1.[illegible]5625	.[illegible]	.1700162E-05	.8712737E-06

NODE 102	-1.1125	[illegible]	.17[illegible]643E-05	.7913154E-06
NODE 103	-1.16875	0.00000	.1703896E-05	.7099834E-06
NODE 104	-1.22500	[illegible]	.1711613E-05	.6246478E-06
NODE 105	-1.77500	[illegible]	.1551958E-05	0.
NODE 106	-1.83125	0.00000	.1541[illegible]3E-05	0.
NODE 107	-1.88750	[illegible]	.1531683E-05	0.
NODE 108	-1.94375	[illegible]	.1522464E-05	0.
NODE 109	-2.00000	[illegible]	.1513711E-05	0.
NODE 110	-1.28125	[illegible]	.1712710E-05	.5343654E-06
NODE 111	-1.28125	.10000	.1554879E-05	.5323619E-06
NODE 112	-1.5[illegible]	.10000	.1535[illegible]40E-05	.1377036E-06
NODE 113	-1.71875	.10000	.1532048E-05	-.1636381E-08
NODE 114	-1.71875	[illegible]	.1564208E-05	0.
NODE 115	-1.33750	[illegible]	.171[illegible]626E-05	.4378866E-06
NODE 116	-1.33750	.[illegible]45[illegible]	.1634367E-05	.4369214E-06
NODE 117	-1.33750	[illegible]	.1562259E-05	.4352685E-06
NODE 118	-1.41375	[illegible]	.155170[illegible]3E-05	.2877279E-06
NODE 119	-1.5[illegible]	[illegible]	.1544587E-05	.1303339E-06
NODE 120	-1.58125	[illegible]	.1559337E-05	.5467397E-07
NODE 121	-1.66250	[illegible]	.1544933E-05	.1177224E-07
NODE 122	-1.66250	.[illegible]45[illegible]	.1571142E-05	.5123936E-08
NODE 123	-1.66250	[illegible]	.158[illegible]798E-05	0.
NODE 124	-1.36563	[illegible]	.1709130E-05	.3882264E-06
NODE 125	-1.36563	.[illegible]25[illegible]	.1570048E-05	.3855839E-06
NODE 126	-1.5[illegible]	.[illegible]25[illegible]	.1552636E-05	.125368[illegible]1E-06
NODE 127	-1.63438	.03250	.1554466E-05	.2094654E-07
NODE 128	-1.63436	[illegible]	.159031[illegible]E-05	0.
NODE 129	-1.39375	[illegible]	.17[illegible]7046E-05	.3367450E-06
NODE 130	-1.34375	.[illegible]375[illegible]	.163[illegible]6E-05	.3350272E-06
NODE 131	-1.39375	.[illegible]75[illegible]	.157[illegible]34E-05	.3337885E-06
NODE 132	-1.44688	.[illegible]750	.1566914E-05	.2300807E-06
NODE 133	-1.5[illegible]	.[illegible]750	.1561036E-05	.1206407E-06
NODE 134	-1.5[illegible]	.[illegible]75[illegible]	.1565917E-05	.6359669E-07
NODE 135	-1.6[illegible]625	.[illegible]750	.1564[illegible]1E-05	.3022689E-07

NODE 136	-1.60625	.3750	.1590743E-05	.1361193E-07
NODE 137	-1.60625	[illegible]	.1601121E-05	0.
NODE 138	-1.42188	[illegible]	.1705222E-05	.2816503E-06
NODE 139	-1.42188	.0625	.1509967E-05	.2793674E-06
NODE 140	-1.50000	.0625	.1575462E-05	.1104902E-16
NODE 141	-1.57813	.06250	.1578496E-05	.3626637E-07
NODE 142	-1.57813	0.00000	.1613659E-05	0.
NODE 143	-1.45[illegible]	[illegible]	.17[illegible]265[illegible]E-05	.2201620E-06
NODE 144	-1.45000	.02500	.1646642E-05	.2187327E-06
NODE 145	-1.45[illegible]	.05000	.1601450E-05	.2185992E-06
NODE 146	-1.47500	.05000	.1593367E-05	.1600665E-06
NODE 147	-1.50000	.05000	.159[illegible]987E-05	.1003483E-06
NODE 148	-1.52500	.15000	.1593266E-05	.6316,6,E-07
NODE 149	-1.55000	.5000	.1593490E-05	.4201286E-07
NODE 150	-1.55000	.02500	.1617923E-05	.1903184E-07
NODE 151	-1.55000	0.00000	.1623576E-05	0.
NODE 152	-1.46500	[illegible]	.17[illegible]17545E-05	.1820141E-06
NODE 153	-1.46500	.03500	.1620737E-05	.1810784E-06
NODE 154	-1.50000	.03500	.1611198E-05	.8420063E-07
NODE 155	-1.53500	.07500	.1612110E-05	.3553417E-07
NODE 156	-1.53500	0.00000	.1640229E-05	0.
NODE 157	-1.48000	0.00000	.17[illegible]753E-05	.1366938E-06
NODE 158	-1.48000	.01300	.1668070E-05	.1355681E-06
NODE 159	-1.40000	.12000	.1642675E-05	.1355420E-06
NODE 160	-1.43000	.12000	.1637652E-05	.1[illegible]2774E-06
NODE 161	-1.50000	.12000	.1634289E-05	.6439595E-07
NODE 162	-1.51000	.02200	.1635064E-05	.3979466E-07
NODE 163	-1.52000	.02800	.1634178E-05	.2721240E-07
NODE 164	-1.52000	[illegible]	.1647214E-05	.1247936E-07
NODE 165	-1.52000	0.00000	.1654203E-05	0.
NODE 166	-1.48500	0.00000	.17[illegible]5275E-05	.1176698E-06
NODE 167	-1.48647	.01354	.1653435E-05	.1111461E-06
NODE 168	-1.50000	.01300	.1643780E-05	.5575587E-07
NODE 169	-1.51354	.01354	.1646018E-05	.2219801E-07

NODE 170	-1.515[illegible]	[illegible]	.166[illegible]145E-05	0.
NODE 171	-1.49[illegible]	[illegible]	.17[illegible]495E-05	.9596299E-07
NODE 172	-1.49147	.00354	.168267[illegible]E-05	.8817671E-07
NODE 173	-1.49293	.[illegible]707	.16669[illegible]6E-05	.8006869E-07
NODE 174	-1.49647	.00654	.165317[illegible]E-05	.6143549E-07
NODE 175	-1.50[illegible]	[illegible]	.1654334E-05	.4574812E-07
NODE 176	-1.50354	.[illegible]354	.1658079E-05	.2823849E-07
NODE 177	-1.50707	.[illegible]707	.1661089E-05	.1624861E-07
NODE 178	-1.5[illegible]354	.00354	.166657[illegible]E-05	.674[illegible]946E-08
NODE 179	-[illegible].51[illegible]	[illegible]	.1667149E-05	0.
NODE 180	-1.49750	[illegible]	.17[illegible]21[illegible]E-05	.4778139E-07
NODE 181	-1.49823	.00177	.1683694E-05	.4[illegible]E-07
NODE 182	-1.50[illegible]	.00259	.16775[illegible]9E-05	.2282859E-07
NODE 183	-1.50177	.00177	.168[illegible]549E-05	.8185551E-08
NODE 184	-1.50250	[illegible]	.1693612E-05	0.
NODE 185	-1.50[illegible]	[illegible]	.1700118E-05	0.

THE CRACK TIP IS AT NODE 185

*** STRESS INTENSITY FACTORS ***

USING THE Y-DISPL OF NODE 171 K1= 6.01359

As in Example 1, the K_I value corresponding to the applied load (2·0 lbs) is given directly. Nodes 1 and 100 correspond to the load point and the crack mouth, respectively. Accordingly, we have for 1 lb. load:

$$K_I = 3{\cdot}0068 \text{ psi}\sqrt{\text{in}}$$

load point displacement = $22{\cdot}34021 \times 10^{-7}$ in.
crack mouth opening displacement = $9{\cdot}511695 \times 10^{-7}$ in.

3. EXAMPLE 3: DOUBLE NOTCH RING COMPRESSION SPECIMEN (CRACK LINE PRESSURE)

The geometry of a Double Notch Compression (DNC) Specimen is shown in Fig. 10a. Let us choose A = 0·5 in, R_i = 1·0 in, and R_o = 2·0 in, so that the mesh of examples 1 and 2 may again be utilized. For this case however, instead of obtaining a solution for a concentrated load directly, as in Example 2, let us use the crack line pressure concept; the purpose being to illustrate the procedure for applying distributed loads.

In Fig. 10b σ_{yy} is the crack line pressure obtained by analyzing an unflawed ring (no cracks) under the given loads P. In general, crack line stress σ_{yy} may be obtained either by solving the analytical elasticity problem or by performing finite element stress analysis of the unflawed ring. The analytical solution, if available, is of course preferable. For the case under consideration, the stress distribution on the crack line was found by taking the negative of the analytical stress distribution[3] obtained for the unflawed ring when P = 1. The node numbers, nodal coordinates and $\pi.\sigma_{yy}$ of the points lying on the crack line are listed below.

Node	X-coordinate(in)	$\pi\cdot\sigma_{yy}$(psi)
100 (crack mouth)	-1.0	-10.1365
101	-1.05625	- 7.72739
102	-1.1125	- 5.96154
103	-1.16875	- 4.61541
104	-1.225	- 3.55142

Node	X-coordinate(in)	$\pi \cdot \sigma_{yy}$(psi)
110	-1.28125	-2.68151
115	-1.3375	-1.94734
124	-1.36563	-1.61820
129	-1.39375	-1.30913
138	-1.42188	-1.01697
143	-1.45	-0.739051
152	-1.465	-0.595854
157	-1.48	-0.455750
166	-1.485	-0.409688
171	-1.49	-0.363927
180	-1.4975	-0.295833
185 (crack tip)	-1.5	-0.273276

It is noticed that nodes 100, 101, and 102 belong to the same element whose connectivity is: 81 83 102 100 82 95 101 94 (see connectivity data of Example 2). In accordance with the convention shown in Fig. 1, the nodes 100, 101, and 102 form side 3 of the element. In a similar fashion we can identify the group of nodes (102, 103, 104), (104, 110, 115), (115, 124, 129), etc. being side 3 of respective elements to which they belong.

Next, for each element side, such as (100, 101, 102), we have polynomial traction distribution of the form:

$$T_y = A_1 + A_2X + A_3X^2 + A_4X^3 = \sigma_{yy} n_y = \sigma_{yy}$$

$$T_x = B_1 + B_2 + B_3Y^2 + B_4Y^3 = 0$$

where n_y is the only nonzero component of the outward unit normal. For the present case $B_1 = B_2 = B_3 = B_4 = 0$. Assuming a quadratic distribution of T_y, $A_4 = 0$. Then, for each group of nodes, such as (100, 101, 102), the coefficients A_1, A_2, A_3 are found since the coordinates and pressure distribution at each node is known. For the present case this was accomplished by writing a small computer program to solve three linear algebraic simultaneous equations. The result was as follows.

NODE GROUP	A_1	A_2	A_3
100,101,102	51·03588	80·16584	32·35651
102,103,104	28·82489	39.99275	14.19187
104,110,115	17.87724	22.03494	6.82783
115,124,129	12.93540	14.57838	4.01532
129,138,143	10.66238	11.31630	2.84494
143,152,157	9.28895	9.41632	2.18785
157,166,171	8.69650	8.61401	1.91623
171,180,185	8.42768	8.25336	1.79527

Using the displacement boundary conditions shown in Fig. 10b, the SRL01A data for the problem can now be prepared. Since the mesh and displacement boundary conditions remain identical to those of Example 2, only the changes are described in the following.

a. Data set 1: NCONC = 0 (no concentrated loads).
b. Data set 2: Same as Example 2.
c. Data set 3: Same as Example 2.
d. Data set 4: Not present.
e. Data set 5: Same as Example 2.
f. Data set 6: NTYPEL = 1 for those elements along the crack surface.
g. Data set 7: Same as Example 2.
h. Data set 8: Same as Example 2.
i. Data set 9:

```
3
51.03588   80.16584   32.35651  0.0   0.0   0.0   0.0   0.0
3
28.82489   39.99275   14.19187  0.0   0.0   0.0   0.0   0.0
3
17.87724   22.03494    6.82783  0.0   0.0   0.0   0.0   0.0
3
12.93540   14.57838    4.01532  0.0   0.0   0.0   0.0   0.0
```

3

10.66238 11.3163 2.84494 0.0 0.0 0.0 0.0 0.0

3

9.28895 9.41632 2.18785 0.0 0.0 0.0 0.0 0.0

3

8.6965 8.61401 1.91623 0.0 0.0 0.0 0.0 0.0

3

8.42768 8.25336 1.79527 0.0 0.0 0.0 0.0 0.0

j. Data set 10: Same as Example 2.

k. Data set 11: Same as Example 2.

The data image produced by SRL01A, and the finite element solution were as follows.

```
    1  185   52   30    0    2    1   [illegible]    8    0   67    5
        10000000.00000                  .30000
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  123    0    1      0.00000000000000        0.00000000000000
  128    0    1      0.00000000000000        0.00000000000000
  137    0    1      0.00000000000000        0.00000000000000
  142    0    1      0.00000000000000        0.00000000000000
  151    0    1      0.00000000000000        0.00000000000000
  156    0    1      0.00000000000000        0.00000000000000
  165    0    1      0.00000000000000        0.00000000000000
  170    0    1      0.00000000000000        0.00000000000000
  179    0    1      0.00000000000000        0.00000000000000
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  185    0    1      0.00000000000000        0.00000000000000
    1    1    0      0.00000000000000        0.00000000000000
    2    1    0      0.00000000000000        0.00000000000000
    3    1    0      0.00000000000000        0.00000000000000
    4    1    0      0.00000000000000        0.00000000000000
    5    1    0      0.00000000000000        0.00000000000000
    6    1    0      0.00000000000000        0.00000000000000
    7    1    0      0.00000000000000        0.00000000000000
    8    1    0      0.00000000000000        0.00000000000000
    9    1    0      0.00000000000000        0.00000000000000
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9	29	27	7	18	28	17	8	0	1	1.00000
11	31	29	9	19	30	18	10	0	1	1.00000
13	33	31	11	20	32	19	12	0	1	1.00000
23	43	41	21	35	42	34	22	0	1	1.00000
25	45	43	23	36	44	35	24	0	1	1.00000
27	47	45	25	37	46	36	26	0	1	1.00000
29	49	47	27	38	48	37	28	0	1	1.00000
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33	53	51	31	40	52	39	32	0	1	1.00000
43	63	61	41	55	62	54	42	0	1	1.00000
45	65	63	43	56	64	55	44	0	1	1.00000
47	67	65	45	57	66	56	46	0	1	1.00000
49	69	67	47	58	68	57	48	0	1	1.00000
51	71	69	49	59	70	58	50	0	1	1.00000
53	73	71	51	60	72	59	52	0	1	1.00000
63	83	81	61	75	82	74	62	0	1	1.00000
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67	87	85	65	77	86	76	66	0	1	1.00000
69	89	87	67	78	88	77	68	0	1	1.00000
71	91	89	69	79	90	78	70	0	1	1.00000
73	93	91	71	80	92	79	72	0	1	1.00000
81	83	102	100	82	95	101	94	1	1	1.00000
83	85	104	102	84	96	103	95	1	1	1.00000
89	91	107	105	90	98	106	97	0	1	1.00000
91	93	109	107	92	99	108	98	0	1	1.00000
85	117	115	104	111	116	110	96	1	1	1.00000
85	87	119	117	86	112	118	111	0	1	1.00000
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131	133	147	145	132	140	146	139	0	1	1.00000
133	135	149	147	134	141	148	140	0	1	1.00000
149	135	137	151	141	136	142	150	0	1	1.00000
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147	149	163	161	148	155	162	154	0	1	1.00000
145	147	161	159	146	154	160	153	0	1	1.00000
163	149	151	165	155	150	156	164	0	1	1.00000
159	173	171	157	167	172	166	158	1	1	1.00000
159	161	175	173	160	168	174	167	0	1	1.00000
161	163	177	175	162	169	176	168	0	1	1.00000
177	163	165	179	169	164	170	178	0	1	1.00000
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NODE	7	0.00000	1.50000
NODE	8	0.00000	1.63750
NODE	9	0.00000	1.77500
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NODE	11	0.00000	1.88750
NODE	12	0.00000	1.94375
NODE	13	0.00000	2.00000
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NODE	15	-.21287	1.07016
NODE	16	-.23440	1.17838
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NODE	19	-.36116	1.81566
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NODE	22	-.40421	.97585
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NODE	27	-.57403	1.38582
NODE	28	-.62665	1.51286
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NODE	30	-.70079	1.69186
NODE	31	-.72231	1.74382
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NODE	36	-.66750	.99898
NODE	37	-.81735	1.22324
NODE	38	-.96719	1.44750
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NODE	40	-1.08979	1.63099
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NODE	42	-.74689	.74689
NODE	43	-.78666	.78666
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NODE	45	-.86621	.86621
NODE	46	-.96344	.96344
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NODE	48	-1.15789	1.15789
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NODE	50	-1.29489	1.29489
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NODE	66	-1.25879	.52141
NODE	67	-1.38582	.57403
NODE	68	-1.51286	.62665
NODE	69	-1.63989	.67926
NODE	70	-1.69186	.70079
NODE	71	-1.74382	.72231
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NODE	73	-1.84776	.76537
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NODE	75	-1.07016	.26787
NODE	76	-1.17838	.28940
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NODE	79	-1.81536	.41616
NODE	80	-1.91338	.43769
NODE	81	-.99000	.11000
NODE	82	-1.05125	.11000
NODE	83	-1.11250	.11000
NODE	84	-1.16875	.11000
NODE	85	-1.22500	.11000
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NODE	88	-1.63750	.11000
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NODE	90	-1.83125	.11000
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NODE	98	-1.88750	.05500
NODE	99	-1.99000	.05500
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NODE	102	-1.11250	0.00000

NODE 103	-1.16875	0.00000
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NODE 113	-1.71875	.10000
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NODE 115	-1.33750	0.00000
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NODE 121	-1.66250	.09000
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NODE 124	-1.36563	0.00000
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NODE 127	-1.63438	.08250
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NODE 129	-1.39375	0.00000
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NODE 132	-1.44688	.07500
NODE 133	-1.50000	.07500
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NODE 135	-1.60625	.07500
NODE 136	-1.60625	.03750
NODE 137	-1.60625	0.00000
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NODE 139	-1.42188	.06250
NODE 140	-1.50000	.06250
NODE 141	-1.57813	.06250
NODE 142	-1.57813	0.00000
NODE 143	-1.45000	0.00000
NODE 144	-1.45000	.02500
NODE 145	-1.45000	.05000
NODE 146	-1.47500	.05000
NODE 147	-1.50000	.05000
NODE 148	-1.52500	.05000
NODE 149	-1.55000	.05000
NODE 150	-1.55000	.02500
NODE 151	-1.55000	0.00000
NODE 152	-1.46500	0.00000
NODE 153	-1.46500	.03500
NODE 154	-1.50000	.03500
NODE 155	-1.53500	.03500

NODE 156	-1.53500	0.00000
NODE 157	-1.48000	0.00000
NODE 158	-1.48000	.01000
NODE 159	-1.48000	.02000
NODE 160	-1.49000	.02000
NODE 161	-1.50000	.02000
NODE 162	-1.51000	.02000
NODE 163	-1.52000	.02000
NODE 164	-1.52000	.01000
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NODE 167	-1.48647	.01354
NODE 168	-1.50000	.01500
NODE 169	-1.51354	.01354
NODE 170	-1.51500	0.00000
NODE 171	-1.49000	0.00000
NODE 172	-1.49147	.00354
NODE 173	-1.49293	.00707
NODE 174	-1.49647	.00854
NODE 175	-1.50000	.01000
NODE 176	-1.50354	.00854
NODE 177	-1.50707	.00707
NODE 178	-1.50854	.00354
NODE 179	-1.51000	0.00000
NODE 180	-1.49750	0.00000
NODE 181	-1.49823	.00177
NODE 182	-1.50000	.00250
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SIDE 3COEFF OF POLYNOMIAL:	51.03586	80.10584	32.35651	0.00000
	0.00000	0.00000	0.00000	0.00000
SIDE 3COEFF OF POLYNOMIAL:	28.82469	39.99275	14.19187	0.00000
	0.00000	0.00000	0.00000	0.00000
SIDE 3COEFF OF POLYNOMIAL:	17.87724	22.03494	6.82783	0.00000
	0.00000	0.00000	0.00000	0.00000
SIDE 3COEFF OF POLYNOMIAL:	12.93540	14.57838	4.01532	0.00000
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SIDE 3COEFF OF POLYNOMIAL:	10.66238	11.31630	2.84494	0.00000
	0.00000	0.00000	0.00000	0.00000
SIDE 3COEFF OF POLYNOMIAL:	9.28895	9.41632	2.18785	0.00000
	0.00000	0.00000	0.00000	0.00000
SIDE 3COEFF OF POLYNOMIAL:	8.69650	8.614[illegible]1	1.91523	0.00000
	0.00000	0.00000	0.00000	0.00000
SIDE 3COEFF OF POLYNOMIAL:	8.42768	8.25336	1.79527	0.00000
	0.00000	0.00000	0.00000	0.00000

		X-COORD	Y-COORD	X-DISPL	Y-DISPL
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NODE	2	0.00000	1.05625	0.	.4382148E-06
NODE	3	0.00000	1.11250	0.	.4392736E-06
NODE	4	0.00000	1.16875	0.	.4397988E-06
NODE	5	0.00000	1.22500	0.	.4398452E-06
NODE	6	0.00000	1.36250	0.	.4396568E-06
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NODE	8	0.00000	1.63750	0.	.4327746E-06
NODE	9	0.00000	1.77500	0.	.4291522E-06
NODE	10	0.00000	1.83125	0.	.4276635E-06
NODE	11	0.00000	1.88750	0.	.4251886E-06
NODE	12	0.00000	1.94375	0.	.4247441E-06
NODE	13	0.00000	2.00000	0.	.4233382E-06
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NODE	15	-.21287	1.07016	.2059382E-07	.4340513E-06
NODE	16	-.23440	1.17838	.1342163E-07	.4335558E-06
NODE	17	-.28702	1.44291	-.3089431E-08	.4269139E-06
NODE	18	-.33963	1.70745	-.1892948E-07	.4169121E-06
NODE	19	-.36116	1.81566	-.2535488E-07	.4125272E-06
NODE	20	-.38269	1.92388	-.3177242E-07	.4081254E-06
NODE	21	-.38268	.92388	.5763432E-07	.4221086E-06
NODE	22	-.40421	.97585	.5020746E-07	.4209743E-06
NODE	23	-.42574	1.02782	.4309341E-07	.4191559E-06
NODE	24	-.44727	1.07979	.3615836E-07	.4168568E-06
NODE	25	-.46879	1.13175	.2944000E-07	.4141246E-06
NODE	26	-.52141	1.25879	.1346442E-07	.4061255E-06
NODE	27	-.57403	1.38582	-.1969511E-08	.3969832E-06
NODE	28	-.62665	1.51286	-.1727449E-07	.3871662E-06
NODE	29	-.67926	1.63989	-.3238702E-07	.3759779E-06
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NODE	31	-.72231	1.74382	-.4474381E-07	.3686278E-06
NODE	32	-.74384	1.79579	-.5092033E-07	.3645080E-06
NODE	33	-.76537	1.84776	-.5713002E-07	.3603663E-06
NODE	34	-.54490	.81550	.9919983E-07	.4079654E-06
NODE	35	-.60620	.90724	.7954710E-07	.3988131E-06
NODE	36	-.66750	.99898	.6137827E-07	.3876746E-06

NODE	37	-.81735	1.22324	.1973751E-07	.3558595E-06
NODE	38	-.96719	1.44750	-.2020293E-07	.3209886E-06
NODE	39	-1.02849	1.53924	-.3640316E-07	.3055043E-06
NODE	40	-1.08979	1.63099	-.5261174E-07	.2919894E-06
NODE	41	-.70711	.70711	.1438383E-06	.3891588E-06
NODE	42	-.74689	.74689	.1324384E-06	.3801168E-06
NODE	43	-.78666	.78666	.1214541E-06	.3706547E-06
NODE	44	-.82644	.82644	.1109028E-06	.3606539E-06
NODE	45	-.86621	.86621	.1005206E-06	.3502571E-06
NODE	46	-.96344	.96344	.7564346E-07	.3243123E-06
NODE	47	-1.06066	1.06066	.5329767E-07	.2966212E-06
NODE	48	-1.15789	1.15789	.3050564E-07	.2690732E-06
NODE	49	-1.25511	1.25511	.7952857E-08	.2413143E-06
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NODE	51	-1.33466	1.33466	-.1060038E-07	.2184598E-06
NODE	52	-1.37444	1.37444	-.2011871E-07	.2068073E-06
NODE	53	-1.41421	1.41421	-.2950237E-07	.1953612E-06
NODE	54	-.81550	.54490	.2070836E-06	.3789266E-06
NODE	55	-.90724	.60620	.1830427E-06	.3520716E-06
NODE	56	-.99898	.66750	.1545837E-06	.3225125E-06
NODE	57	-1.22324	.81735	.1208940E-06	.2443219E-06
NODE	58	-1.44750	.96719	.7974203E-07	.1680751E-06
NODE	59	-1.53924	1.02849	.6225553E-07	.1355441E-06
NODE	60	-1.63099	1.08979	.4458590E-07	.1049317E-06
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NODE	62	-.97585	.40421	.2646015E-06	.3506908E-06
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NODE	66	-1.25879	.52141	.2198642E-06	.2284827E-06
NODE	67	-1.38582	.57403	.2063226E-06	.1756932E-06
NODE	68	-1.51286	.62665	.1939152E-06	.1274377E-06
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NODE	71	-1.74382	.72231	.1658594E-06	.3935621E-07
NODE	72	-1.79579	.74384	.1580607E-06	.1847364E-07
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NODE	76	-1.17838	.28940	.3107287E-06	.2748778E-06
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NODE	79	-1.81566	.41616	.2932021E-06	-.9410083E-09
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NODE	81	-.99000	.11000	.4143283E-06	.4627816E-06
NODE	82	-1.05125	.11000	.4104922E-06	.3710053E-06
NODE	83	-1.11250	.11000	.4074814E-06	.3360161E-06
NODE	84	-1.16875	.11000	.4052182E-06	.3621560E-06
NODE	85	-1.22500	.11000	.4031339E-06	.2668191E-06
NODE	86	-1.36250	.11000	.3955435E-06	.1663771E-06
NODE	87	-1.50000	.11000	.3947739E-06	.6133475E-07
NODE	88	-1.63750	.11000	.3988677E-06	.1533421E-07
NODE	89	-1.77500	.11000	.3980034E-06	.7827378E-09
NODE	90	-1.83125	.11000	.3967045E-06	-.4246841E-08
NODE	91	-1.88750	.11000	.3949257E-06	-.9455361E-08
NODE	92	-1.93375	.11000	.3936746E-06	-.1441879E-07
NODE	93	-1.98000	.11000	.3919154E-06	-.2059384E-07
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NODE	95	-1.11250	.05500	.4409198E-06	.3459889E-06
NODE	96	-1.22500	.05500	.4375769E-06	.2721314E-06
NODE	97	-1.77500	.05500	.4065484E-06	-.7351116E-10
NODE	98	-1.88750	.05500	.4019749E-06	-.5130259E-08
NODE	99	-1.99000	.05500	.3972865E-06	-.9775673E-08
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NODE	101	-1.05625	0.00000	.4785015E-06	.3936844E-06
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NODE	105	-1.77500	0.00000	.4099470E-06	0.
NODE	106	-1.83125	0.00000	.4067433E-06	0.
NODE	107	-1.88750	0.00000	.4040310E-06	0.
NODE	108	-1.94375	0.00000	.4018844E-06	0.
NODE	109	-2.00000	0.00000	.3986944E-06	0.
NODE	110	-1.28125	0.00000	.4754245E-06	.2361128E-06

NODE 111	-1.28125	.10000	.4059664E-06	.2272696E-06
NODE 112	-1.50000	.10000	.3989580E-06	.5877110E-07
NODE 113	-1.71875	.10000	.4013326E-06	.2896702E-08
NODE 114	-1.71875	0.00000	.4140022E-06	0.
NODE 115	-1.33750	0.00000	.4740766E-06	.1924488E-06
NODE 116	-1.33750	.04500	.4401944E-06	.1894644E-06
NODE 117	-1.33750	.09000	.4090027E-06	.1862310E-06
NODE 118	-1.41875	.09000	.4049565E-06	.1228975E-06
NODE 119	-1.50000	.09000	.4028820E-06	.5566050E-07
NODE 120	-1.58125	.09000	.4055914E-06	.2438249E-07
NODE 121	-1.66250	.09000	.4055325E-06	.7305343E-08
NODE 122	-1.66250	.04500	.4161763E-06	.3326484E-08
NODE 123	-1.66250	0.00000	.4201042E-06	0.
NODE 124	-1.36563	0.00000	.4733229E-06	.1701712E-06
NODE 125	-1.36563	.08250	.4124207E-06	.1652076E-06
NODE 126	-1.50000	.08250	.4062622E-06	.5354023E-07
NODE 127	-1.63438	.08250	.4090916E-06	.1061549E-07
NODE 128	-1.63438	0.00000	.4237339E-06	0.
NODE 129	-1.39375	0.00000	.4723694E-06	.1472057E-06
NODE 130	-1.39375	.03750	.4421082E-06	.1450603E-06
NODE 131	-1.39375	.07500	.4154451E-06	.1431691E-06
NODE 132	-1.44688	.07500	.4116456E-06	.9850609E-07
NODE 133	-1.50000	.07500	.4097396E-06	.5132596E-07
NODE 134	-1.55313	.07500	.4126050E-06	.2758249E-07
NODE 135	-1.60625	.07500	.4125966E-06	.1405469E-07
NODE 136	-1.60625	.03750	.4236458E-06	.6368961E-08
NODE 137	-1.60625	0.00000	.4279641E-06	0.
NODE 138	-1.42188	0.00000	.4715842E-06	.1227746E-06
NODE 139	-1.42188	.06250	.4212685E-06	.1200416E-06
NODE 140	-1.50000	.06250	.4158459E-06	.4729364E-07
NODE 141	-1.57813	.06250	.4182217E-06	.1613708E-07
NODE 142	-1.57813	0.00000	.4329952E-06	0.
NODE 143	-1.45000	0.00000	.4715232E-06	.9569367E-07
NODE 144	-1.45000	.02500	.4460454E-06	.9456479E-07
NODE 145	-1.45000	.05000	.4254506E-06	.9402748E-07
NODE 146	-1.47500	.05000	.4234675E-06	.6873816E-07
NODE 147	-1.50000	.05000	.4224552E-06	.4300892E-07

NODE 148	-1.52500	.05000	.4237377E-06	.2714086E-07
NODE 149	-1.55000	.05000	.4241537E-06	.1823869E-07
NODE 150	-1.55000	.02500	.4345464E-06	.8257207E-08
NODE 151	-1.55000	0.00000	.4395274E-06	0.
NODE 152	-1.46500	0.00000	.4711845E-06	.7897521E-07
NODE 153	-1.46500	.03500	.4349204E-06	.7832419E-07
NODE 154	-1.50000	.03500	.4310847E-06	.3617571E-07
NODE 155	-1.53500	.03500	.4319071E-06	.1530207E-07
NODE 156	-1.53500	0.00000	.4439617E-06	0.
NODE 157	-1.48000	0.00000	.4697920E-06	.5920523E-07
NODE 158	-1.48000	.01000	.4555892E-06	.5850120E-07
NODE 159	-1.48000	.02000	.4445577E-06	.5847725E-07
NODE 160	-1.49000	.02000	.4420918E-06	.4520365E-07
NODE 161	-1.50000	.02000	.4411914E-06	.2759038E-07
NODE 162	-1.51000	.02000	.4415249E-06	.1707590E-07
NODE 163	-1.52000	.02000	.4412332E-06	.1166864E-07
NODE 164	-1.52000	.01000	.4438675E-06	.5345645E-08
NODE 165	-1.52000	0.00000	.4498892E-06	0.
NODE 166	-1.48500	0.00000	.4697106E-06	.5093736E-07
NODE 167	-1.48547	.01354	.4492842E-06	.4797099E-07
NODE 168	-1.50000	.01500	.4452039E-06	.2399167E-07
NODE 169	-1.51354	.01354	.4452911E-06	.9515105E-08
NODE 170	-1.51500	0.00000	.4524105E-06	0.
NODE 171	-1.49000	0.00000	.4696773E-06	.4151658E-07
NODE 172	-1.49147	.00354	.4619997E-06	.3811193E-07
NODE 173	-1.49293	.00707	.4551773E-06	.3457941E-07
NODE 174	-1.49647	.00854	.4518522E-06	.2649717E-07
NODE 175	-1.50000	.01000	.4497829E-06	.1970111E-07
NODE 176	-1.50354	.00854	.4514298E-06	.1214376E-07
NODE 177	-1.50707	.00707	.4527581E-06	.5972841E-08
NODE 178	-1.50854	.00354	.4551408E-06	.2838728E-08
NODE 179	-1.51000	0.00000	.4553028E-06	0.
NODE 180	-1.49750	0.00000	.4696267E-06	.2065517E-07
NODE 181	-1.49823	.00177	.4624825E-06	.1728564E-07
NODE 182	-1.50000	.00250	.4598174E-06	.9847982E-08
NODE 183	-1.50177	.00177	.4611857E-06	.3524644E-08
NODE 184	-1.50250	0.00000	.4624709E-06	0.
NODE 185	-1.50000	0.00000	.4695915E-06	0.

THE CRACK TIP IS AT NODE 185

*** STRESS INTENSITY FACTORS ***

USING THE Y-DISPL OF NODE 171 K1= 2.60167

The above results show that K_I for the problem is $2 \cdot 60167$ psi$\sqrt{in.}$ The same problem of double notch ring compression specimen when solved by applying concentrated load P directly (Fig. 10a) gave stress intensity factor value of $2 \cdot 59355$ psi$\sqrt{in.}$ The 0.3% difference in the two values could be attributed to round-off error in the calculation of nodal stresses from elasticity solution and in the evaluation of pressure polynomial constants. Further, the assumption of quadratic pressure distribution over each element side may have contributed to the difference. An interesting exercise would be to try constant, linear, and cubic pressure polynomials.

4. EXAMPLE 4: COMPACT TYPE SPECIMENS

One of the advantages of using programmed mesh generation along with the finite element program is that changes in geometry pose no difficulty. For a compact tension test specimen (Fig. 11) of standard geometry (H/W = 0.6) and for WOL specimen (H/W = 0.486) SRL01A results can be found in reference 4. For the present example we choose the following dimensions:

$H = 1.2$ in.
$W = 2.4$ in.
$W_1 = 3.05$ in.
$S = 0.0938$ in.
$F = 1.417$ in.
$E' = 0.55$ in.
$R = 0.25$ in.
$\theta = 40.0$ deg.
$A = 1.2$ in.

The mesh generation program SRLCMP (Appendix I) was executed using the following cards:

Job Card

ATTACH,LGO,SRLCMP,ID=M760328.

ATTACH,TAPE8,SRLCM,CY=2,ID=M760328.

LGO.

End-of-record card

1·2 0.55 1·417 1·2 0·0938 40·0 2·4 3·05 0·25 0·55

End-of-job Card

The last entry on the data cards is the distance n - n (Fig. 11). This distance should always be kept less than 2 × E' and larger than S. The location of point n can be chosen to correspond with the actual COD measurement location in an experimental set-up.

The use of plotting program SRL11 provided the mesh plots shown in Fig. 12. Due to symmetry about the crack axis, only the upper half of the geometry is used in the analysis. The displacement and force boundary conditions are shown in Fig. 13. The crack tip is fixed in both X and Y directions to eliminate rigid body motion.

The data image produced by SRL01A was as follows:

```
   1 330  34  15   1   2   1 100   6   0 119   5
     10000000.00000                  .30000
 106   1   1        0.00000000000000     0.00000000000000
 107   1   1        0.00000000000000     0.00000000000000
 108   1   1        0.00000000000000     0.00000000000000
 104   0   1        0.00000000000000     0.00000000000000
 100   0   1        0.00000000000000     0.00000000000000
  92   0   1        0.00000000000000     0.00000000000000
  94   0   1        0.00000000000000     0.00000000000000
  85   0   1        0.00000000000000     0.00000000000000
  70   0   1        0.00000000000000     0.00000000000000
  62   0   1        0.00000000000000     0.00000000000000
  47   0   1        0.00000000000000     0.00000000000000
  39   0   1        0.00000000000000     0.00000000000000
  24   0   1        0.00000000000000     0.00000000000000
  16   0   1        0.00000000000000     0.00000000000000
   1   0   1        0.00000000000000     0.00000000000000
 277           0.0000000000         1.0000000000
```

3	26	24	1	17	25	16	2	1	1	1.00000
5	28	26	3	18	27	17	4	1	1	1.00000
7	30	28	5	19	29	18	6	1	1	1.00000
9	32	30	7	20	31	19	8	1	1	1.00000
11	34	32	9	21	33	20	10	1	1	1.00000
13	36	34	11	22	35	21	12	1	1	1.00000
15	38	36	13	23	37	22	14	1	1	1.00000
26	49	47	24	40	48	39	25	1	1	1.00000
28	51	49	26	41	50	40	27	1	1	1.00000
30	53	51	28	42	52	41	29	1	1	1.00000
32	55	53	30	43	54	42	31	1	1	1.00000
34	57	55	32	44	56	43	33	1	1	1.00000
36	59	57	34	45	58	44	35	1	1	1.00000
38	61	59	36	46	60	45	37	1	1	1.00000
49	72	70	47	63	71	62	48	1	1	1.00000
51	74	72	49	64	73	63	50	1	1	1.00000
53	76	74	51	65	75	64	52	1	1	1.00000
55	78	76	53	66	77	65	54	1	1	1.00000
57	80	78	55	67	79	66	56	1	1	1.00000
59	82	80	57	68	81	67	58	1	1	1.00000
61	84	82	59	69	83	68	60	1	1	1.00000
74	116	114	72	88	115	87	73	1	1	1.00000
76	118	116	74	89	117	88	75	1	1	1.00000
78	120	118	76	90	119	89	77	1	1	1.00000
80	122	120	78	91	121	90	79	1	1	1.00000
82	124	122	80	92	123	91	81	1	1	1.00000
84	126	124	82	93	125	92	83	1	1	1.00000
116	152	150	114	140	151	139	115	1	1	1.00000
118	154	152	116	141	153	140	117	1	1	1.00000
120	156	154	118	142	155	141	119	1	1	1.00000
122	158	156	120	143	157	142	121	1	1	1.00000
124	160	158	122	144	159	143	123	1	1	1.00000
126	162	160	124	145	161	144	125	1	1	1.00000
150	173	171	148	164	172	163	149	1	1	1.00000
152	175	173	150	165	174	164	151	1	1	1.00000
154	177	175	152	166	176	165	153	1	1	1.00000
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177	200	198	175	189	199	188	176	1	1	1.00000
179	202	200	177	190	201	189	178	1	1	1.00000
181	204	202	179	191	203	190	180	1	1	1.00000
183	206	204	181	192	205	191	182	1	1	1.00000
185	208	206	183	193	207	192	184	1	1	1.00000
196	219	217	194	210	218	209	195	1	1	1.00000
198	221	219	196	211	220	210	197	1	1	1.00000
200	223	221	198	212	222	211	199	1	1	1.00000
202	225	223	200	213	224	212	201	1	1	1.00000

204	227	225	202	214	226	213	203	1	1	1.00000
206	229	227	204	215	228	214	205	1	1	1.00000
208	231	229	206	216	230	215	207	1	1	1.00000
221	241	239	219	233	240	232	220	1	1	1.00000
223	243	241	221	234	242	233	222	1	1	1.00000
225	245	243	223	235	244	234	224	1	1	1.00000
227	247	245	225	236	246	235	226	1	1	1.00000
229	249	247	227	237	248	236	228	1	1	1.00000
231	251	249	229	238	250	237	230	1	1	1.00000
241	263	261	239	253	262	252	240	1	1	1.00000
243	265	263	241	254	264	253	242	1	1	1.00000
245	267	265	243	255	266	254	244	1	1	1.00000
251	281	273	249	260	280	259	250	1	1	1.00000
263	297	295	261	283	296	282	262	1	1	1.00000
265	299	297	263	284	298	283	264	1	1	1.00000
267	301	299	265	285	300	284	266	1	1	1.00000
281	307	305	279	294	306	293	280	1	1	1.00000
297	320	318	295	312	319	311	296	1	1	1.00000
299	322	320	297	313	321	312	298	1	1	1.00000
301	324	322	299	314	323	313	300	1	1	1.00000
303	326	324	301	315	325	314	302	1	1	1.00000
305	328	326	303	316	327	315	304	1	1	1.00000
307	330	328	305	317	329	316	306	1	1	1.00000
249	275	273	247	258	274	257	248	1	1	1.00000
249	279	277	275	259	278	276	258	1	1	1.00000
279	305	291	277	293	310	292	278	1	1	1.00000
291	305	303	289	310	304	309	290	1	1	1.00000
289	303	301	287	309	302	308	288	1	1	1.00000
269	267	301	267	286	308	285	268	1	1	1.00000
247	273	271	245	257	272	256	246	1	1	1.00000
271	265	267	245	270	268	255	256	1	1	1.00000
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102	110	106	106	103	109	107	105	1	1	1.00000
110	131	106	108	132	128	107	109	1	1	1.00000
131	129	106	108	130	127	107	128	1	1	1.00000
96	102	100	94	99	101	98	95	1	1	1.00000
96	112	110	102	97	111	103	99	1	1	1.00000
112	137	131	110	138	134	132	111	1	1	1.00000
137	135	129	131	136	133	130	134	1	1	1.00000
72	96	94	70	86	95	85	71	1	1	1.00000
72	114	112	96	87	113	97	85	1	1	1.00000
114	150	137	112	139	147	138	113	1	1	1.00000
137	150	148	135	147	149	146	136	1	1	1.00000

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.9562500E-01	.1229300E+00	NODE	64
.9562500E-01	.1989700E+00	NODE	65
.9562500E-01	.2750000E+00	NODE	66
.9562500E-01	.5500000E+00	NODE	67
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.6000000E-01	.1229300E+00	NODE	74
.6000000E-01	.1609500E+00	NODE	75
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.6000000E-01	.2369850E+00	NODE	77
.6000000E-01	.2750000E+00	NODE	78
.6000000E-01	.4125000E+00	NODE	79
.6000000E-01	.5500000E+00	NODE	80
.6000000E-01	.7750000E+00	NODE	81
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.3000000E-01	.1000000E+01	NODE	92
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.3750000E-02	0.	NODE	104
.2650000E-02	.2650000E-02	NODE	105

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0.	0.	NODE 107
0.	0.	NODE 108
0.	.3750000E-02	NODE 109
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0.	.2400000E-01	NODE 112
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0.	.4690000E-01	NODE 114
0.	.8491500E-01	NODE 115
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0.	.2750000E+00	NODE 120
0.	.4125000E+00	NODE 121
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0.	.7750000E+00	NODE 123
0.	.1000000E+01	NODE 124
0.	.1100000E+01	NODE 125
0.	.1200000E+01	NODE 126
-.3750000E-02	0.	NODE 127
-.2650000E-02	.2650000E-02	NODE 128
-.1500000E-01	0.	NODE 129
-.1280500E-01	.5305000E-02	NODE 130
-.1061000E-01	.1061000E-01	NODE 131
-.5305000E-02	.1280500E-01	NODE 132
-.1950000E-01	0.	NODE 133
-.1379000E-01	.1379000E-01	NODE 134
-.2400000E-01	0.	NODE 135
-.2048500E-01	.8485000E-02	NODE 136
-.1697000E-01	.1697000E-01	NODE 137
-.8485000E-02	.2048500E-01	NODE 138
-.3000000E-01	.4690000E-01	NODE 139
-.3000000E-01	.1229300E+00	NODE 140
-.3000000E-01	.1989700E+00	NODE 141
-.3000000E-01	.2750000E+00	NODE 142
-.3000000E-01	.5500000E+00	NODE 143
-.3000000E-01	.1000000E+01	NODE 144
-.3000000E-01	.1200000E+01	NODE 145
-.4200000E-01	0.	NODE 146
-.3848500E-01	.3193500E-01	NODE 147
-.6000000E-01	0.	NODE 148
-.6000000E-01	.2345000E-01	NODE 149
-.6000000E-01	.4690000E-01	NODE 150
-.6000000E-01	.8491500E-01	NODE 151
-.6000000E-01	.1229300E+00	NODE 152
-.6000000E-01	.1609500E+00	NODE 153
-.6000000E-01	.1989700E+00	NODE 154
-.6000000E-01	.2369950E+00	NODE 155
-.6000000E-01	.2750000E+00	NODE 156
-.6000000E-01	.4125000E+00	NODE 157
-.6000000E-01	.5500000E+00	NODE 158
-.6000000E-01	.7750000E+00	NODE 159
-.6000000E-01	.1000000E+01	NODE 160

-.6000000E-01	.1100000E+01	NODE 161
~~-.6000000E-01~~	~~.1200000E+01~~	~~NODE 162~~
-.8331500E-01	0.	NODE 163
~~-.8331500E-01~~	~~.4690000E-01~~	~~NODE 164~~
-.8331500E-01	.1229300E+00	NODE 165
~~-.8331500E-01~~	~~.1989700E+00~~	~~NODE 166~~
-.8331500E-01	.2750000E+00	NODE 167
~~-.8331500E-01~~	~~.5500000E+00~~	~~NODE 168~~
-.8331500E-01	.1000000E+01	NODE 169
~~-.8331500E-01~~	~~.1200000E+01~~	~~NODE 170~~
-.1066300E+00	0.	NODE 171
~~-.1066300E+00~~	~~.2345000E-01~~	~~NODE 172~~
-.1066300E+00	.4690000E-01	NODE 173
~~-.1066300E+00~~	~~.8491500E-01~~	~~NODE 174~~
-.1066300E+00	.1229300E+00	NODE 175
~~-.1066300E+00~~	~~.1609500E+00~~	~~NODE 176~~
-.1066300E+00	.1989700E+00	NODE 177
~~-.1066300E+00~~	~~.2369850E+00~~	~~NODE 178~~
-.1066300E+00	.2750000E+00	NODE 179
~~-.1066300E+00~~	~~.4125000E+00~~	~~NODE 180~~
-.1066300E+00	.5500000E+00	NODE 181
~~-.1066300E+00~~	~~.7750000E+00~~	~~NODE 182~~
-.1066300E+00	.1000000E+01	NODE 183
~~-.1066300E+00~~	~~.1100000E+01~~	~~NODE 184~~
-.1066300E+00	.1200000E+01	NODE 185
~~-.1610250E+00~~	~~0.~~	~~NODE 186~~
-.1610250E+00	.4690000E-01	NODE 187
~~-.1610250E+00~~	~~.1229300E+00~~	~~NODE 188~~
-.1610250E+00	.1989700E+00	NODE 189
~~-.1610250E+00~~	~~.2750000E+00~~	~~NODE 190~~
-.1610250E+00	.5500000E+00	NODE 191
~~-.1610250E+00~~	~~.1000000E+01~~	~~NODE 192~~
-.1610250E+00	.1200000E+01	NODE 193
-.2154200E+00	~~0.~~	~~NODE 194~~
-.2154200E+00	.2345000E-01	NODE 195
~~-.2154200E+00~~	~~.4690000E-01~~	~~NODE 196~~
-.2154200E+00	.8491500E-01	NODE 197
~~-.2154200E+00~~	~~.1229300E+00~~	~~NODE 198~~
-.2154200E+00	.1609500E+00	NODE 199
~~-.2154200E+00~~	~~.1989700E+00~~	~~NODE 200~~
-.2154200E+00	.2369850E+00	NODE 201
~~-.2154200E+00~~	~~.2750000E+00~~	~~NODE 202~~
-.2154200E+00	.4125000E+00	NODE 203
~~-.2154200E+00~~	~~.5500000E+00~~	~~NODE 204~~
-.2154200E+00	.7750000E+00	NODE 205
~~-.2154200E+00~~	~~.1000000E+01~~	~~NODE 206~~
-.2154200E+00	.1100000E+01	NODE 207
~~-.2154200E+00~~	~~.1200000E+01~~	~~NODE 208~~
-.3242100E+00	0.	NODE 209
-.3886400E+00	.4690000E-01	NODE 210
-.3886400E+00	.1229300E+00	NODE 211
~~-.3886400E+00~~	~~.1989700E+00~~	~~NODE 212~~
-.3886400E+00	.2750000E+00	NODE 213
~~-.3886400E+00~~	~~.5500000E+00~~	~~NODE 214~~
-.3886400E+00	.1000000E+01	NODE 215

-.3886400E+00	.1200000E+01	NODE 216
-.4330000E+00	0.	NODE 217
-.4974300E+00	.2345000E-01	NODE 218
-.5618600E+00	.4690000E-01	NODE 219
-.5618600E+00	.8491500E-01	NODE 220
-.5618600E+00	.1229300E+00	NODE 221
-.5618600E+00	.1609500E+00	NODE 222
-.5618600E+00	.1989700E+00	NODE 223
-.5618600E+00	.2369850E+00	NODE 224
-.5618600E+00	.2750000E+00	NODE 225
-.5618600E+00	.4125000E+00	NODE 226
-.5618600E+00	.5500000E+00	NODE 227
-.5618600E+00	.7750000E+00	NODE 228
-.5618600E+00	.1000000E+01	NODE 229
-.5618600E+00	.1100000E+01	NODE 230
-.5618600E+00	.1200000E+01	NODE 231
-.6588950E+00	.4690000E-01	NODE 232
-.6588950E+00	.1229300E+00	NODE 233
-.6588950E+00	.1989700E+00	NODE 234
-.6588950E+00	.2750000E+00	NODE 235
-.6588950E+00	.5500000E+00	NODE 236
-.6588950E+00	.1000000E+01	NODE 237
-.6588950E+00	.1200000E+01	NODE 238
-.7559300E+00	.4690000E-01	NODE 239
-.7559300E+00	.8491500E-01	NODE 240
-.7559300E+00	.1229300E+00	NODE 241
-.7559300E+00	.1609500E+00	NODE 242
-.7559300E+00	.1989700E+00	NODE 243
-.7559300E+00	.2369850E+00	NODE 244
-.7559300E+00	.2750000E+00	NODE 245
-.7559300E+00	.4125000E+00	NODE 246
-.7559300E+00	.5500000E+00	NODE 247
-.7559300E+00	.7750000E+00	NODE 248
-.7559300E+00	.1000000E+01	NODE 249
-.7559300E+00	.1100000E+01	NODE 250
-.7559300E+00	.1200000E+01	NODE 251
-.9779650E+00	.4690000E-01	NODE 252
-.9779650E+00	.1229300E+00	NODE 253
-.9779650E+00	.1989700E+00	NODE 254
-.9779650E+00	.2750000E+00	NODE 255
-.8895900E+00	.3241250E+00	NODE 256
-.8529650E+00	.5500000E+00	NODE 257
-.8895900E+00	.8633750E+00	NODE 258
-.9779650E+00	.1000000E+01	NODE 259
-.9779650E+00	.1200000E+01	NODE 260
-.1200000E+01	.4690000E-01	NODE 261
-.1200000E+01	.8491500E-01	NODE 262
-.1200000E+01	.1229300E+00	NODE 263
-.1200000E+01	.1609500E+00	NODE 264
-.1200000E+01	.1989700E+00	NODE 265
-.1200000E+01	.2369850E+00	NODE 266
-.1200000E+01	.2750000E+00	NODE 267
-.1200000E+01	.2875000E+00	NODE 268
-.1200000E+01	.3000000E+00	NODE 269
-.1111625E+01	.3366250E+00	NODE 270

-.1023250E+01	.3732500E+00	NODE 271
-.9866250E+00	.4616250E+00	NODE 272
-.9500000E+00	.5500000E+00	NODE 273
-.9866250E+00	.6383750E+00	NODE 274
-.1023250E+01	.7267500E+00	NODE 275
-.1111625E+01	.7633750E+00	NODE 276
-.1200000E+01	.8000000E+00	NODE 277
-.1200000E+01	.9000000E+00	NODE 278
-.1200000E+01	.1000000E+01	NODE 279
-.1200000E+01	.1100000E+01	NODE 280
-.1200000E+01	.1200000E+01	NODE 281
-.1425000E+01	.4690000E-01	NODE 282
-.1425000E+01	.1229300E+00	NODE 283
-.1425000E+01	.1989700E+00	NODE 284
-.1425000E+01	.2750000E+00	NODE 285
-.1288375E+01	.3366250E+00	NODE 286
-.1376750E+01	.3732500E+00	NODE 287
-.1413375E+01	.4616250E+00	NODE 288
-.1450000E+01	.5500000E+00	NODE 289
-.1413375E+01	.6383750E+00	NODE 290
-.1376750E+01	.7267500E+00	NODE 291
-.1288375E+01	.7633750E+00	NODE 292
-.1425000E+01	.1000000E+01	NODE 293
-.1425000E+01	.1200000E+01	NODE 294
-.1650000E+01	.4690000E-01	NODE 295
-.1650000E+01	.8491500E-01	NODE 296
-.1650000E+01	.1229300E+00	NODE 297
-.1650000E+01	.1609500E+00	NODE 298
-.1650000E+01	.1989700E+00	NODE 299
-.1650000E+01	.2369550E+00	NODE 300
-.1650000E+01	.2750000E+00	NODE 301
-.1650000E+01	.4125000E+00	NODE 302
-.1650000E+01	.5500000E+00	NODE 303
-.1650000E+01	.7750000E+00	NODE 304
-.1650000E+01	.1000000E+01	NODE 305
-.1650000E+01	.1100000E+01	NODE 306
-.1650000E+01	.1200000E+01	NODE 307
-.1513375E+01	.3241250E+00	NODE 308
-.1550000E+01	.5500000E+00	NODE 309
-.1513375E+01	.8633750E+00	NODE 310
-.1750000E+01	.4690000E-01	NODE 311
-.1750000E+01	.1229300E+00	NODE 312
-.1750000E+01	.1989700E+00	NODE 313
-.1750000E+01	.2750000E+00	NODE 314
-.1750000E+01	.5500000E+00	NODE 315
-.1750000E+01	.1000000E+01	NODE 316
-.1750000E+01	.1200000E+01	NODE 317
-.1850000E+01	.4690000E-01	NODE 318
-.1850000E+01	.8491500E-01	NODE 319
-.1850000E+01	.1229300E+00	NODE 320
-.1850000E+01	.1609500E+00	NODE 321
-.1850000E+01	.1989700E+00	NODE 322

-.1850000E+01	.2369850E+00	NODE 323
~~-.1850000E+01~~	~~.2750000E+00~~	~~NODE 324~~
-.1850000E+01	.4125000E+00	NODE 325
~~-.1850000E+01~~	~~.5500000E+00~~	~~NODE 326~~
-.1850000E+01	.7750000E+00	NODE 327
~~-.1850000E+01~~	~~.1000000E+01~~	~~NODE 328~~
-.1850000E+01	.1100000E+01	NODE 329
~~-.1850000E+01~~	~~.1200000E+01~~	~~NODE 330~~

The results of the analysis are summarized below:

$K_I = 6\cdot59341$ psi$\sqrt{in}$

$\delta_{m-m} = 66\cdot43846 \times 10^{-7}$ in

$\delta_{1-1} = 43\cdot76998 \times 10^{-7}$ in

$\delta_{p-p} = 48\cdot98702 \times 10^{-7}$ in

$\delta_{g-g} = 46\cdot30266 \times 10^{-7}$ in

The points m, 1, p, and g are indicated in Fig. 11 and these correspond to nodes 318, 261, 277, and 281 on the mesh respectively. The displacement values shown above were obtained by multiplying the V-displacements of the corresponding points by two.

5. EXAMPLE 5: THREE POINT BEND SPECIMENS

The geometry of a three point bend specimen is shown in Fig. 14. The data for this problem was generated by using the program of subsection 4 of Appendix I, and the following dimensions:

L = 4·25 in. , P' = 0·0625 in.

S = 4.0 in. , THETA = 40.0 deg.

W = 1.0 in. , G = 0.2 in.

G' = 0.375 in. , A = 0.5 in.

N = 0.25 in. , H = 0.125 in.

B = 1.0 in.

The data image produced by SRL01A was as follows:

1	340	99	17	2	2	1	80	6	0	121	5

10000000.01000 .30000

284	0	1	0.000000000000	0.000000000000
285	0	1	0.000000000000	0.000000000000
286	0	1	0.000000000000	0.000000000000
287	0	1	0.000000000000	0.000000000000
288	0	1	0.000000000000	0.000000000000
289	0	1	0.000000000000	0.000000000000
290	0	1	0.000000000000	0.000000000000
295	0	1	0.000000000000	0.000000000000
304	0	1	0.000000000000	0.000000000000
309	0	1	0.000000000000	0.000000000000
318	0	1	0.000000000000	0.000000000000
323	0	1	0.000000000000	0.000000000000
332	0	1	0.000000000000	0.000000000000
337	0	1	0.000000000000	0.000000000000
338	1	1	0.000000000000	0.000000000000
339	1	1	0.000000000000	0.000000000000
340	1	1	0.000000000000	0.000000000000

30	.5000000000	0.0000000000
298	-.5000000000	0.0000000000

32	3	1	30	21	2	20	31	1	1	1.00000
34	5	3	32	22	4	21	33	1	1	1.00000
36	7	5	34	23	6	22	35	1	1	1.00000
38	9	7	36	24	8	23	37	1	1	1.00000
40	11	9	38	25	10	24	39	1	1	1.00000
42	13	11	40	26	12	25	41	1	1	1.00000
44	15	13	42	27	14	26	43	1	1	1.00000
46	17	15	44	28	16	27	45	1	1	1.00000
48	19	17	46	29	18	28	47	1	1	1.00000
61	32	30	59	50	31	49	60	1	1	1.00000
63	34	32	61	51	33	50	62	1	1	1.00000
65	36	34	63	52	35	51	64	1	1	1.00000
67	38	36	65	53	37	52	66	1	1	1.00000
69	40	38	67	54	39	53	68	1	1	1.00000
71	42	40	69	55	41	54	70	1	1	1.00000
73	44	42	71	56	43	55	72	1	1	1.00000
75	46	44	73	57	45	56	74	1	1	1.00000
77	48	46	75	58	47	57	76	1	1	1.00000
90	61	59	88	79	60	78	89	1	1	1.00000
92	63	61	90	80	62	79	91	1	1	1.00000
94	65	63	92	81	64	80	93	1	1	1.00000
96	67	65	94	82	66	81	95	1	1	1.00000
98	69	67	96	83	68	82	97	1	1	1.00000
100	71	69	98	84	70	83	99	1	1	1.00000
102	73	71	100	85	72	84	101	1	1	1.00000
104	75	73	102	86	74	85	103	1	1	1.00000
106	77	75	104	87	76	86	105	1	1	1.00000
119	90	88	117	108	89	107	118	1	1	1.00000
121	92	90	119	109	91	108	120	1	1	1.00000
123	94	92	121	110	93	109	122	1	1	1.00000
125	96	94	123	111	95	110	124	1	1	1.00000
127	98	96	125	112	97	111	126	1	1	1.00000

129	100	98	127	113	99	112	128	1	1	1.00000
131	102	100	129	114	101	113	130	1	1	1.00000
133	104	102	131	115	103	114	132	1	1	1.00000
135	106	104	133	116	105	115	134	1	1	1.00000
148	119	117	146	137	118	136	147	1	1	1.00000
150	121	119	148	138	120	137	149	1	1	1.00000
152	123	121	150	139	122	138	151	1	1	1.00000
154	125	123	152	140	124	139	153	1	1	1.00000
156	127	125	154	141	126	140	155	1	1	1.00000
158	129	127	156	142	128	141	157	1	1	1.00000
160	131	129	158	143	130	142	159	1	1	1.00000
162	133	131	160	144	132	143	161	1	1	1.00000
164	135	133	162	145	134	144	163	1	1	1.00000
177	148	146	175	166	147	165	176	1	1	1.00000
179	150	148	177	167	149	166	178	1	1	1.00000
181	152	150	179	168	151	167	180	1	1	1.00000
183	154	152	181	169	153	168	182	1	1	1.00000
185	156	154	183	170	155	169	184	1	1	1.00000
187	158	156	185	171	157	170	186	1	1	1.00000
189	160	158	187	172	159	171	188	1	1	1.00000
191	162	160	189	173	161	172	190	1	1	1.00000
193	164	162	191	174	163	173	192	1	1	1.00000
205	179	177	203	195	178	194	204	1	1	1.00000
207	181	179	205	196	180	195	206	1	1	1.00000
209	183	181	207	197	182	196	208	1	1	1.00000
211	185	183	209	198	184	197	210	1	1	1.00000
213	187	185	211	199	186	198	212	1	1	1.00000
215	189	187	213	200	188	199	214	1	1	1.00000
217	191	189	215	201	190	200	216	1	1	1.00000
219	193	191	217	202	192	201	218	1	1	1.00000
231	205	203	229	221	204	220	230	1	1	1.00000
233	207	205	231	222	206	221	232	1	1	1.00000
235	209	207	233	223	208	222	234	1	1	1.00000
237	211	209	235	224	210	223	236	1	1	1.00000
239	213	211	237	225	212	224	238	1	1	1.00000
241	215	213	239	226	214	225	240	1	1	1.00000
243	217	215	241	227	216	226	242	1	1	1.00000
245	219	217	243	228	218	227	244	1	1	1.00000
257	231	229	255	247	230	246	256	1	1	1.00000
259	233	231	257	248	232	247	258	1	1	1.00000
261	235	233	259	249	234	248	260	1	1	1.00000
263	237	235	261	250	236	249	262	1	1	1.00000
265	239	237	263	251	238	250	264	1	1	1.00000
267	241	239	265	252	240	251	266	1	1	1.00000
269	243	241	267	253	242	252	268	1	1	1.00000
271	245	243	269	254	244	253	270	1	1	1.00000
281	259	257	279	273	258	272	280	1	1	1.00000
283	261	259	281	274	260	273	282	1	1	1.00000
286	267	265	284	276	266	275	285	1	1	1.00000
288	269	267	286	277	268	276	287	1	1	1.00000
290	271	269	288	278	270	277	289	1	1	1.00000
265	302	304	284	294	303	295	275	1	1	1.00000
265	263	300	302	264	293	301	294	1	1	1.00000

263	261	298	300	262	292	299	293	1	1	1.00000
298	261	283	296	292	274	291	297	1	1	1.00000
302	316	318	304	308	317	309	303	1	1	1.00000
302	300	314	316	301	307	315	308	1	1	1.00000
300	298	312	314	299	306	313	307	1	1	1.00000
312	298	296	310	306	297	305	311	1	1	1.00000
316	330	332	318	322	331	323	317	1	1	1.00000
316	314	328	330	315	321	329	322	1	1	1.00000
314	312	326	328	313	320	327	321	1	1	1.00000
326	312	310	324	320	311	319	325	1	1	1.00000
330	338	340	332	336	339	337	331	1	1	1.00000
328	338	340	330	335	339	336	329	1	1	1.00000
326	338	340	328	334	339	335	327	1	1	1.00000
324	336	340	326	333	339	334	325	1	1	1.00000

-.5000000E+00	.2125000E+01	NODE	1
-.4687500E+00	.2125000E+01	NODE	2
-.4375000E+00	.2125000E+01	NODE	3
-.4190750E+00	.2125000E+01	NODE	4
-.4006500E+00	.2125000E+01	NODE	5
-.2628250E+00	.2125000E+01	NODE	6
-.1250000E+00	.2125000E+01	NODE	7
-.9375000E-01	.2125000E+01	NODE	8
-.6250000E-01	.2125000E+01	NODE	9
-.3125000E-01	.2125000E+01	NODE	10
0.	.2125000E+01	NODE	11
.3125000E-01	.2125000E+01	NODE	12
.6250000E-01	.2125000E+01	NODE	13
.1250000E+00	.2125000E+01	NODE	14
.1875000E+00	.2125000E+01	NODE	15
.2916650E+00	.2125000E+01	NODE	16
.3958300E+00	.2125000E+01	NODE	17
.4479150E+00	.2125000E+01	NODE	18
.5000000E+00	.2125000E+01	NODE	19
-.5000000E+00	.2062500E+01	NODE	20
-.4375000E+00	.2062500E+01	NODE	21
-.4006500E+00	.2062500E+01	NODE	22
-.1250000E+00	.2062500E+01	NODE	23
-.6250000E-01	.2062500E+01	NODE	24
0.	.2062500E+01	NODE	25
.6250000E-01	.2062500E+01	NODE	26
.1875000E+00	.2062500E+01	NODE	27
.3958300E+00	.2062500E+01	NODE	28
.5000000E+00	.2062500E+01	NODE	29
-.5000000E+00	.2000000E+01	NODE	30
-.4687500E+00	.2000000E+01	NODE	31
-.4375000E+00	.2000000E+01	NODE	32
-.4190750E+00	.2000000E+01	NODE	33
-.4006500E+00	.2000000E+01	NODE	34
-.2628250E+00	.2000000E+01	NODE	35
-.1250000E+00	.2000000E+01	NODE	36
-.9375000E-01	.2000000E+01	NODE	37
-.6250000E-01	.2000000E+01	NODE	38
-.3125000E-01	.2000000E+01	NODE	39

0.	.2000000E+01	NODE	40
.3125000E-01	.2000000E+01	NODE	41
.6250000E-01	.2000000E+01	NODE	42
.1250000E+00	.2000000E+01	NODE	43
.1875000E+00	.2000000E+01	NODE	44
.2916650E+00	.2000000E+01	NODE	45
.3958300E+00	.2000000E+01	NODE	46
.4479150E+00	.2000000E+01	NODE	47
.5000000E+00	.2000000E+01	NODE	48
-.5000000E+00	.1708335E+01	NODE	49
-.4375000E+00	.1708335E+01	NODE	50
-.4006500E+00	.1708335E+01	NODE	51
-.1250000E+00	.1708335E+01	NODE	52
-.6250000E-01	.1708335E+01	NODE	53
0.	.1708335E+01	NODE	54
.6250000E-01	.1708335E+01	NODE	55
.1875000E+00	.1708335E+01	NODE	56
.3958300E+00	.1708335E+01	NODE	57
.5000000E+00	.1708335E+01	NODE	58
-.5000000E+00	.1416670E+01	NODE	59
-.4687500E+00	.1416670E+01	NODE	60
-.4375000E+00	.1416670E+01	NODE	61
-.4190750E+00	.1416670E+01	NODE	62
-.4006500E+00	.1416670E+01	NODE	63
-.2628250E+00	.1416670E+01	NODE	64
-.1250000E+00	.1416670E+01	NODE	65
-.9375000E-01	.1416670E+01	NODE	66
-.6250000E-01	.1416670E+01	NODE	67
-.3125000E-01	.1416670E+01	NODE	68
0.	.1416670E+01	NODE	69
.3125000E-01	.1416670E+01	NODE	70
.6250000E-01	.1416670E+01	NODE	71
.1250000E+00	.1416670E+01	NODE	72
.1875000E+00	.1416670E+01	NODE	73
.2916650E+00	.1416670E+01	NODE	74
.3958300E+00	.1416670E+01	NODE	75
.4479150E+00	.1416670E+01	NODE	76
.5000000E+00	.1416670E+01	NODE	77
-.5000000E+00	.1208335E+01	NODE	78
-.4375000E+00	.1208335E+01	NODE	79
-.4006500E+00	.1208335E+01	NODE	80
-.1250000E+00	.1208335E+01	NODE	81
-.6250000E-01	.1208335E+01	NODE	82
0.	.1208335E+01	NODE	83
.6250000E-01	.1208335E+01	NODE	84
.1875000E+00	.1208335E+01	NODE	85
.3958300E+00	.1208335E+01	NODE	86
.5000000E+00	.1208335E+01	NODE	87
-.5000000E+00	.1000000E+01	NODE	88
-.4687500E+00	.1000000E+01	NODE	89
-.4375000E+00	.1000000E+01	NODE	90
-.4190750E+00	.1000000E+01	NODE	91
-.4006500E+00	.1000000E+01	NODE	92

-.2628250E+00	.1000000E+01	NODE	93
-.1250000E+00	.1000000E+01	NODE	94
-.9375000E-01	.1000000E+01	NODE	95
-.6250000E-01	.1000000E+01	NODE	96
-.3125000E-01	.1000000E+01	NODE	97
0.	.1000000E+01	NODE	98
.3125000E-01	.1000000E+01	NODE	99
.6250000E-01	.1000000E+01	NODE	100
.1250000E+00	.1000000E+01	NODE	101
.1875000E+00	.1000000E+01	NODE	102
.2916650E+00	.1000000E+01	NODE	103
.3958300E+00	.1000000E+01	NODE	104
.4479150E+00	.1000000E+01	NODE	105
.5000000E+00	.1000000E+01	NODE	106
-.5000000E+00	.7916650E+00	NODE	107
-.4375000E+00	.7916650E+00	NODE	108
-.4006500E+00	.7916650E+00	NODE	109
-.1250000E+00	.7916650E+00	NODE	110
-.6250000E-01	.7916650E+00	NODE	111
0.	.7916650E+00	NODE	112
.6250000E-01	.7916650E+00	NODE	113
.1875000E+00	.7916650E+00	NODE	114
.3958300E+00	.7916650E+00	NODE	115
.5000000E+00	.7916650E+00	NODE	116
-.5000000E+00	.5833300E+00	NODE	117
-.4687500E+00	.5833300E+00	NODE	118
-.4375000E+00	.5833300E+00	NODE	119
-.4190750E+00	.5833300E+00	NODE	120
-.4006500E+00	.5833300E+00	NODE	121
-.2628250E+00	.5833300E+00	NODE	122
-.1250000E+00	.5833300E+00	NODE	123
-.9375000E-01	.5833300E+00	NODE	124
-.6250000E-01	.5833300E+00	NODE	125
-.3125000E-01	.5833300E+00	NODE	126
0.	.5833300E+00	NODE	127
.3125000E-01	.5833300E+00	NODE	128
.6250000E-01	.5833300E+00	NODE	129
.1250000E+00	.5833300E+00	NODE	130
.1875000E+00	.5833300E+00	NODE	131
.2916650E+00	.5833300E+00	NODE	132
.3958300E+00	.5833300E+00	NODE	133
.4479150E+00	.5833300E+00	NODE	134
.5000000E+00	.5833300E+00	NODE	135
-.5000000E+00	.4791650E+00	NODE	136
-.4375000E+00	.4791650E+00	NODE	137
-.4006500E+00	.4791650E+00	NODE	138
-.1250000E+00	.4791650E+00	NODE	139
-.6250000E-01	.4791650E+00	NODE	140
0.	.4791650E+00	NODE	141
.6250000E-01	.4791650E+00	NODE	142
.1875000E+00	.4791650E+00	NODE	143
.3958300E+00	.4791650E+00	NODE	144
.5000000E+00	.4791650E+00	NODE	145

-.5000000E+00	.3750000E+00	NODE 146
-.4687500E+00	.3750000E+00	NODE 147
-.4375000E+00	.3750000E+00	NODE 148
-.4190750E+00	.3750000E+00	NODE 149
-.4006500E+00	.3750000E+00	NODE 150
-.2628250E+00	.3750000E+00	NODE 151
-.1250000E+00	.3750000E+00	NODE 152
-.9375000E-01	.3750000E+00	NODE 153
-.6250000E-01	.3750000E+00	NODE 154
-.3125000E-01	.3750000E+00	NODE 155
0.	.3750000E+00	NODE 156
.3125000E-01	.3750000E+00	NODE 157
.6250000E-01	.3750000E+00	NODE 158
.1250000E+00	.3750000E+00	NODE 159
.1875000E+00	.3750000E+00	NODE 160
.2916650E+00	.3750000E+00	NODE 161
.3958300E+00	.3750000E+00	NODE 162
.4479150E+00	.3750000E+00	NODE 163
.5000000E+00	.3750000E+00	NODE 164
-.5000000E+00	.2812500E+00	NODE 165
-.4375000E+00	.2812500E+00	NODE 166
-.4006500E+00	.2812500E+00	NODE 167
-.1250000E+00	.2812500E+00	NODE 168
-.6250000E-01	.2812500E+00	NODE 169
0.	.2812500E+00	NODE 170
.6250000E-01	.2812500E+00	NODE 171
.1875000E+00	.2812500E+00	NODE 172
.3958300E+00	.2812500E+00	NODE 173
.5000000E+00	.2812500E+00	NODE 174
-.5000000E+00	.1875000E+00	NODE 175
-.4687500E+00	.1875000E+00	NODE 176
-.4375000E+00	.1875000E+00	NODE 177
-.4190750E+00	.1875000E+00	NODE 178
-.4006500E+00	.1875000E+00	NODE 179
-.2628250E+00	.1875000E+00	NODE 180
-.1250000E+00	.1875000E+00	NODE 181
-.9375000E-01	.1875000E+00	NODE 182
-.6250000E-01	.1875000E+00	NODE 183
-.3125000E-01	.1875000E+00	NODE 184
0.	.1875000E+00	NODE 185
.3125000E-01	.1875000E+00	NODE 186
.6250000E-01	.1875000E+00	NODE 187
.1250000E+00	.1875000E+00	NODE 188
.1875000E+00	.1875000E+00	NODE 189
.2916650E+00	.1875000E+00	NODE 190
.3958300E+00	.1875000E+00	NODE 191
.4479150E+00	.1875000E+00	NODE 192
.5000000E+00	.1875000E+00	NODE 193
-.4375000E+00	.1656250E+00	NODE 194
-.4006500E+00	.1656250E+00	NODE 195
-.1250000E+00	.1656250E+00	NODE 196
-.6250000E-01	.1656250E+00	NODE 197
0.	.1656250E+00	NODE 198

.6250000E-01	.1656250E+00	NODE 199
.1875000E+00	.1656250E+00	NODE 200
.3958300E+00	.1656250E+00	NODE 201
.5000000E+00	.1656250E+00	NODE 202
-.4375000E+00	.1437500E+00	NODE 203
-.4190750E+00	.1437500E+00	NODE 204
-.4006500E+00	.1437500E+00	NODE 205
-.2628250E+00	.1437500E+00	NODE 206
-.1250000E+00	.1437500E+00	NODE 207
-.9375000E-01	.1437500E+00	NODE 208
-.6250000E-01	.1437500E+00	NODE 209
-.3125000E-01	.1437500E+00	NODE 210
0.	.1437500E+00	NODE 211
.3125000E-01	.1437500E+00	NODE 212
.6250000E-01	.1437500E+00	NODE 213
.1250000E+00	.1437500E+00	NODE 214
.1875000E+00	.1437500E+00	NODE 215
.2916650E+00	.1437500E+00	NODE 216
.3958300E+00	.1437500E+00	NODE 217
.4479150E+00	.1437500E+00	NODE 218
.5000000E+00	.1437500E+00	NODE 219
-.4375000E+00	.1218750E+00	NODE 220
-.4006500E+00	.1218750E+00	NODE 221
-.1250000E+00	.1218750E+00	NODE 222
-.6250000E-01	.1218750E+00	NODE 223
0.	.1218750E+00	NODE 224
.6250000E-01	.1218750E+00	NODE 225
.1875000E+00	.1218750E+00	NODE 226
.3958300E+00	.1218750E+00	NODE 227
.5000000E+00	.1218750E+00	NODE 228
-.4375000E+00	.1000000E+00	NODE 229
-.4190750E+00	.1000000E+00	NODE 230
-.4006500E+00	.1000000E+00	NODE 231
-.2628250E+00	.1000000E+00	NODE 232
-.1250000E+00	.1000000E+00	NODE 233
-.9375000E-01	.1000000E+00	NODE 234
-.6250000E-01	.1000000E+00	NODE 235
-.3125000E-01	.1000000E+00	NODE 236
0.	.1000000E+00	NODE 237
.3125000E-01	.1000000E+00	NODE 238
.6250000E-01	.1000000E+00	NODE 239
.1250000E+00	.1000000E+00	NODE 240
.1875000E+00	.1000000E+00	NODE 241
.2916650E+00	.1000000E+00	NODE 242
.3958300E+00	.1000000E+00	NODE 243
.4479150E+00	.1000000E+00	NODE 244
.5000000E+00	.1000000E+00	NODE 245
-.4375000E+00	.8125000E-01	NODE 246
-.4006500E+00	.8125000E-01	NODE 247
-.1250000E+00	.8125000E-01	NODE 248
-.6250000E-01	.8125000E-01	NODE 249
0.	.8125000E-01	NODE 250
.6250000E-01	.8125000E-01	NODE 251

.1875000E+00	.8125000E-01	NODE 252
.3958300E+00	.8125000E-01	NODE 253
.5000000E+00	.8125000E-01	NODE 254
-.4375000E+00	.6250000E-01	NODE 255
-.4190750E+00	.6250000E-01	NODE 256
-.4006500E+00	.6250000E-01	NODE 257
-.2628250E+00	.6250000E-01	NODE 258
-.1250000E+00	.6250000E-01	NODE 259
-.9375000E-01	.6250000E-01	NODE 260
-.6250000E-01	.6250000E-01	NODE 261
-.3125000E-01	.6250000E-01	NODE 262
0.	.6250000E-01	NODE 263
.3125000E-01	.6250000E-01	NODE 264
.6250000E-01	.6250000E-01	NODE 265
.1250000E+00	.6250000E-01	NODE 266
.1875000E+00	.6250000E-01	NODE 267
.2916650E+00	.6250000E-01	NODE 268
.3958300E+00	.6250000E-01	NODE 269
.4479150E+00	.6250000E-01	NODE 270
.5000000E+00	.6250000E-01	NODE 271
-.3253250E+00	.3125000E-01	NODE 272
-.1250000E+00	.3125000E-01	NODE 273
-.6250000E-01	.3125000E-01	NODE 274
.6250000E-01	.3125000E-01	NODE 275
.1875000E+00	.3125000E-01	NODE 276
.3958300E+00	.3125000E-01	NODE 277
.5000000E+00	.3125000E-01	NODE 278
-.2500000E+00	0.	NODE 279
-.1875000E+00	0.	NODE 280
-.1250000E+00	0.	NODE 281
-.9375000E-01	0.	NODE 282
-.6250000E-01	0.	NODE 283
.6250000E-01	0.	NODE 284
.1250000E+00	0.	NODE 285
.1875000E+00	0.	NODE 286
.2916650E+00	0.	NODE 287
.3958300E+00	0.	NODE 288
.4479150E+00	0.	NODE 289
.5000000E+00	0.	NODE 290
-.4687500E-01	0.	NODE 291
-.4687500E-01	.4687500E-01	NODE 292
0.	.4687500E-01	NODE 293
.4687500E-01	.4687500E-01	NODE 294
.4687500E-01	0.	NODE 295
-.3125000E-01	0.	NODE 296
-.3125000E-01	.1562500E-01	NODE 297
-.3125000E-01	.3125000E-01	NODE 298
-.1562500E-01	.3125000E-01	NODE 299
0.	.3125000E-01	NODE 300
.1562500E-01	.3125000E-01	NODE 301
.3125000E-01	.3125000E-01	NODE 302
.3125000E-01	.1562500E-01	NODE 303
.3125000E-01	0.	NODE 304

-.2187500E-01	0.	NODE 305
-.2187500E-01	.2187500E-01	NODE 306
0.	.2187500E-01	NODE 307
.2187500E-01	.2187500E-01	NODE 308
.2187500E-01	0.	NODE 309
-.1250000E-01	0.	NODE 310
-.1250000E-01	.6250000E-02	NODE 311
-.1250000E-01	.1250000E-01	NODE 312
-.6250000E-02	.1250000E-01	NODE 313
0.	.1250000E-01	NODE 314
.6250000E-02	.1250000E-01	NODE 315
.1250000E-01	.1250000E-01	NODE 316
.1250000E-01	.6250000E-02	NODE 317
.1250000E-01	0.	NODE 318
-.9375000E-02	0.	NODE 319
-.8460000E-02	.8460000E-02	NODE 320
0.	.9375000E-02	NODE 321
.8460000E-02	.8460000E-02	NODE 322
.9375000E-02	0.	NODE 323
-.6250000E-02	0.	NODE 324
-.5335000E-02	.2210000E-02	NODE 325
-.4420000E-02	.4420000E-02	NODE 326
-.2210000E-02	.5335000E-02	NODE 327
0.	.6250000E-02	NODE 328
.2210000E-02	.5335000E-02	NODE 329
.4420000E-02	.4420000E-02	NODE 330
.5335000E-02	.2210000E-02	NODE 331
.6250000E-02	0.	NODE 332
-.1560000E-02	0.	NODE 333
-.1100000E-02	.1100000E-02	NODE 334
0.	.1560000E-02	NODE 335
.1100000E-02	.1100000E-02	NODE 336
.1560000E-02	0.	NODE 337
0.	0.	NODE 338
0.	0.	NODE 339
0.	0.	NODE 340

In this case loads of 0.5 lbs. are applied at points 1 and p (Fig. 14), and the crack tip is fixed in both directions. Therefore the total load point displacement is the sum of the magnitudes of vertical displacements of points p and 1. In Fig. 14, G represents the location of clip gage to measure the crack opening displacement. The result of the analysis gave the following values of stress intensity factor, load point displacement and the crack opening displacement:

$K_I = 10.6892 \text{ psi}\sqrt{\text{in}}$

Load point displacement = 58.01097×10^{-7} in.

Crack opening displacement = 16.02759×10^{-7} in.

On the mesh points p and 1 correspond to nodes 30 and 290, respectively. Crack opening displacement is twice the Y displacement of node 229.

6. EXAMPLE 6: SINGLE NOTCH RING SPECIMEN

Single notch specimens in the shape of circular rings are shown in Fig. 15. The program of subsection 2 of Appendix I generates the data for single notch ring compression specimen (Fig. 15a). The data for the tension case is generated by changing the loading condition.

Choosing A = 0.5 in., R_i = 1.0 in and R_o = 2.0 in., the mesh generation program was used to produce the required data for SRL01A. The data image produced by SRL01A, which corresponds to the mesh of Fig. 16 was as follows.

1	267	76	32	2	2	1	70	6	0	96	5

10000000.00000	.30000

1	0	1	0.000000000000	0.000000000000
2	0	1	0.000000000000	0.000000000000
3	[illegible]	1	[illegible]	[illegible]
4	0	1	0.000000000000	0.000000000000
5	0	1	0.000000000000	0.000000000000
6	0	1	0.000000000000	0.000000000000
7	0	1	0.000000000000	[illegible]
8	[illegible]	1	0.000000000000	0.000000000000
9	0	1	0.000000000000	0.000000000000
10	0	1	0.000000000000	0.000000000000
11	0	1	0.000000000000	0.00[illegible]
12	[illegible]	1	0.000000000000	0.000000000000
13	0	1	0.000000000000	0.000000000000
165	0	1	0.000000000000	0.000000000000
166	0	1	0.000000000000	0.000000000000
167	[illegible]	1	[illegible]	[illegible]
168	0	1	0.000000000000	0.000000000000
169	0	1	0.000000000000	0.000000000000
194	0	1	0.000000000000	0.000000000000
203	0	1	0.0000000[illegible]	[illegible]
208	0	1	0.000000000000	0.000000000000
217	0	1	0.000000000000	0.000000000000
222	0	1	0.000000000000	0.000000000000
231	0	1	0.000000000000	0.000000000000
236	[illegible]	1	[illegible]	[illegible]000000000000
245	0	1	0.000000000000	0.000000000000
250	0	1	0.000000000000	0.000000000000
259	0	1	0.000000000000	0.000000000000
264	0	1	[illegible]	[illegible]
265	1	1	0.000000000000	0.000000000000
266	1	1	0.000000000000	0.000000000000
267	1	1	0.000000000000	0.000000000000

61	0.00000000000	1.0000000000
63	[illegible]	0.0000000000

3	23	21	1	15	22	14	2	1	1	1.00000
5	25	23	3	16	24	15	4	1	1	1.00000
7	27	25	5	17	26	16	6	1	1	1.00000
9	29	27	7	18	28	17	8	1	1	[illegible]
11	31	29	9	19	30	18	10	1	1	1.00000
13	33	31	11	20	32	19	12	1	1	1.00000
23	43	41	21	35	42	34	22	1	1	1.00000
25	45	43	23	36	44	35	24	1	1	[illegible]
27	47	45	25	37	46	36	26	1	1	1.00000
29	49	47	27	38	48	37	28	1	1	1.00000
31	51	49	29	39	50	38	30	1	1	1.00000
33	53	51	31	40	52	39	32	1	1	1.00000
43	63	61	41	55	62	54	42	1	1	1.00000
45	65	63	43	56	64	55	44	1	1	1.00000
47	67	65	45	57	66	56	46	1	1	1.00000
49	69	67	47	58	68	57	48	1	1	1.00000
51	71	69	49	59	70	58	5[illegible]	1	1	[illegible]

53	73	71	51	60	72	59	52	1	1	1.00000
63	83	81	61	75	82	74	62	1	1	1.00000
65	85	83	63	76	84	75	64	1	1	1.00000
67	87	85	65	77	86	76	66	1	1	1.00000
69	89	87	57	78	88	77	68	1	1	1.00000
71	91	89	69	79	90	78	70	1	1	1.00000
73	93	91	71	80	92	79	72	1	1	1.00000
83	103	101	81	95	102	94	82	1	1	1.00000
85	105	103	83	96	104	95	84	1	1	1.00000
87	107	105	85	97	106	96	86	1	1	1.00000
89	109	107	87	98	108	97	88	1	1	1.00000
91	111	109	89	99	110	98	90	1	1	1.00000
93	113	111	91	100	112	99	92	1	1	1.00000
103	123	121	101	115	122	114	102	1	1	1.00000
105	125	123	103	116	124	115	104	1	1	1.00000
107	127	125	105	117	126	116	106	1	1	1.00000
109	129	127	107	118	128	117	108	1	1	1.00000
111	131	129	109	119	130	118	110	1	1	1.00000
113	133	131	111	120	132	119	112	1	1	1.00000
123	143	141	121	135	142	134	122	1	1	1.00000
125	145	143	123	136	144	135	124	1	1	1.00000
127	147	145	125	137	146	136	126	1	1	1.00000
129	149	147	127	138	148	137	128	1	1	1.00000
131	151	149	129	139	150	138	130	1	1	1.00000
133	153	151	131	140	152	139	132	1	1	1.00000
143	163	161	141	155	162	154	142	1	1	1.00000
145	165	163	143	156	164	155	144	1	1	1.00000
147	167	165	145	157	166	156	146	1	1	1.00000
149	169	167	147	158	168	157	148	1	1	1.00000
151	171	169	149	159	170	158	150	1	1	1.00000
153	173	171	151	160	172	159	152	1	1	1.00000
161	163	182	180	162	175	181	174	1	1	1.00000
163	165	184	152	164	176	183	175	1	1	1.00000
169	171	187	185	170	178	186	177	1	1	1.00000
171	173	189	187	172	179	188	178	1	1	1.00000
165	187	195	164	181	196	190	176	1	1	1.00000
165	167	199	157	166	192	193	191	1	1	1.00000
167	169	201	199	168	193	200	192	1	1	1.00000
201	169	155	203	193	177	194	202	1	1	1.00000
197	211	209	195	205	210	204	196	1	1	1.00000
197	199	213	211	198	206	212	205	1	1	1.00000
199	201	215	213	200	207	214	206	1	1	1.00000
215	201	203	217	207	202	208	216	1	1	1.00000
211	225	223	209	219	224	216	210	1	1	1.00000
211	213	227	225	212	220	226	219	1	.	1.00000
213	215	229	227	214	221	228	220	1	1	1.00000
225	215	217	231	221	216	222	230	1	1	1.00000
225	239	237	223	233	238	232	224	1	1	1.00000
277	229	243	241	228	235	242	234	1	1	1.00000
229	227	241	239	226	234	240	233	1	1	1.00000
243	225	231	245	235	230	236	244	1	1	1.00000
[illegible]	[illegible]	251	237	247	252	246	238	1	1	1.00000

239	241	255	253	240	248	254	247	1	1	1.00000
241	243	257	255	242	249	256	248	1	1	1.00000
257	243	245	259	249	244	250	258	1	1	1.00000
253	265	267	251	261	266	260	252	1	1	1.00000
255	265	267	253	262	266	261	254	1	1	1.00000
257	265	267	255	263	266	262	256	1	1	1.00000
259	265	267	257	264	266	263	258	1	1	1.00000

.1000000E+01	0.	NODE	1
.1083335E+01	0.	NODE	2
.1166670E+01	0.	NODE	3
.1250000E+01	0.	NODE	4
.1333330E+01	0.	NODE	5
.1416665E+01	0.	NODE	6
.1500000E+01	0.	NODE	7
.1583335E+01	0.	NODE	8
.1666670E+01	0.	NODE	9
.1750000E+01	0.	NODE	10
.1833330E+01	0.	NODE	11
.1916665E+01	0.	NODE	12
.2000000E+01	0.	NODE	13
.9619400E+00	.1913400E+00	NODE	14
.1122265E+01	.2232300E+00	NODE	15
.1282585E+01	.2551200E+00	NODE	16
.1442910E+01	.2870150E+00	NODE	17
.1603235E+01	.3189050E+00	NODE	18
.1763555E+01	.3507950E+00	NODE	19
.1923680E+01	.3826350E+00	NODE	20
.9238800E+00	.3826800E+00	NODE	21
.1000870E+01	.4145700E+00	NODE	22
.1077660E+01	.4464600E+00	NODE	23
.1154850E+01	.4783500E+00	NODE	24
.1231640E+01	.5102400E+00	NODE	25
.1308830E+01	.5421350E+00	NODE	26
.1385620E+01	.5740300E+00	NODE	27
.1462810E+01	.6059200E+00	NODE	28
.1539800E+01	.6378100E+00	NODE	29
.1616790E+01	.6697000E+00	NODE	30
.1693780E+01	.7015900E+00	NODE	31
.1770770E+01	.7334800E+00	NODE	32
.1847760E+01	.7653700E+00	NODE	33
.8154950E+00	.5448950E+00	NODE	34
.9514100E+00	.6357100E+00	NODE	35
.1087325E+01	.7265250E+00	NODE	36
.1223240E+01	.8173450E+00	NODE	37
.1359155E+01	.9081600E+00	NODE	38
.1495070E+01	.9989750E+00	NODE	39
.1630985E+01	.1089790E+01	NODE	40
.7071100E+00	.7071100E+00	NODE	41
.7660350E+00	.7660350E+00	NODE	42
.8249600E+00	.8249600E+00	NODE	43
.8838350E+00	.8838350E+00	NODE	44
.9428100E+00	.9428100E+00	NODE	45
.1[illegible]1735E+01	.1[illegible]1735E+01	NODE	46

.1060660E+01	.1060660E+01	NODE 47
.1119585E+01	.1119585E+01	NODE 48
.1178510E+01	.1178510E+01	NODE 49
.1237435E+01	.1237435E+01	NODE 50
.1296360E+01	.1296360E+01	NODE 51
.1355285E+01	.1355285E+01	NODE 52
.1414210E+01	.1414210E+01	NODE 53
.5448950E+00	.8154950E+00	NODE 54
.6357100E+00	.9514140E+00	NODE 55
.7265250E+00	.1087325E+01	NODE 56
.8173450E+00	.1223240E+01	NODE 57
.9081600E+00	.1359155E+01	NODE 58
.9989750E+00	.1495070E+01	NODE 59
.1089790E+01	.1630985E+01	NODE 60
.3826600E+00	.9238800E+00	NODE 61
.4145700E+00	.1000870E+01	NODE 62
.4464600E+00	.1077360E+01	NODE 63
.4783550E+00	.1154850E+01	NODE 64
.5102400E+00	.1231340E+01	NODE 65
.5421350E+00	.1308830E+01	NODE 66
.5740300E+00	.1385320E+01	NODE 67
.6059250E+00	.1462810E+01	NODE 68
.6378100E+00	.1539800E+01	NODE 69
.6697000E+00	.1616790E+01	NODE 70
.7015900E+00	.1693780E+01	NODE 71
.7334800E+00	.1770770E+01	NODE 72
.7653700E+00	.1847760E+01	NODE 73
.1913400E+00	.9619400E+00	NODE 74
.2232300E+00	.1122265E+01	NODE 75
.2551200E+00	.1282585E+01	NODE 76
.2870150E+00	.1442910E+01	NODE 77
.3189050E+00	.1603235E+01	NODE 78
.3507950E+00	.1763555E+01	NODE 79
.3826850E+00	.1923880E+01	NODE 80
0.	.1000000E+01	NODE 81
0.	.1083335E+01	NODE 82
0.	.1166670E+01	NODE 83
0.	.1250000E+01	NODE 84
0.	.1333330E+01	NODE 85
0.	.1416665E+01	NODE 86
0.	.1500000E+01	NODE 87
0.	.1583335E+01	NODE 88
0.	.1666670E+01	NODE 89
0.	.1750000E+01	NODE 90
0.	.1833330E+01	NODE 91
0.	.1916665E+01	NODE 92
0.	.2000000E+01	NODE 93
-.1913400E+00	.9619400E+00	NODE 94
-.2232300E+00	.1122265E+01	NODE 95
-.2551200E+00	.1282585E+01	NODE 96
-.2870150E+00	.1442910E+01	NODE 97
-.3189050E+00	.1603235E+01	NODE 98
-.3507950E+00	.1763555E+01	NODE 99

-.3826850E+00	.1923880E+01	NODE 100
-.3826600E+00	.9238800E+00	NODE 101
-.4145700E+00	.1000870E+01	NODE 102
-.4464600E+00	.1077860E+01	NODE 103
-.4783500E+00	.1154850E+01	NODE 104
-.5102400E+00	.1231840E+01	NODE 105
-.5421350E+00	.1308830E+01	NODE 106
-.5740300E+00	.1385620E+01	NODE 107
-.6059200E+00	.1462810E+01	NODE 108
-.6378100E+00	.1539800E+01	NODE 109
-.6697000E+00	.1616750E+01	NODE 110
-.7015900E+00	.1693780E+01	NODE 111
-.7334800E+00	.1770770E+01	NODE 112
-.7653700E+00	.1847760E+01	NODE 113
-.5448950E+00	.8154950E+00	NODE 114
-.6357100E+00	.9514100E+00	NODE 115
-.7265250E+00	.1087325E+01	NODE 116
-.8173450E+00	.1223240E+01	NODE 117
-.9081600E+00	.1359155E+01	NODE 118
-.9989750E+00	.1495070E+01	NODE 119
-.1089790E+01	.1630985E+01	NODE 120
-.7071100E+00	.7071100E+00	NODE 121
-.7660350E+00	.7660350E+00	NODE 122
-.8249600E+00	.8249600E+00	NODE 123
-.8838850E+00	.8838850E+00	NODE 124
-.9428100E+00	.9428100E+00	NODE 125
-.1001735E+01	.1001735E+01	NODE 126
-.1060660E+01	.1060660E+01	NODE 127
-.1119585E+01	.1119585E+01	NODE 128
-.1178510E+01	.1178510E+01	NODE 129
-.1237435E+01	.1237435E+01	NODE 130
-.1296360E+01	.1296360E+01	NODE 131
-.1355285E+01	.1355285E+01	NODE 132
-.1414210E+01	.1414210E+01	NODE 133
-.8154950E+00	.5448950E+00	NODE 134
-.9514100E+00	.6357100E+00	NODE 135
-.1087325E+01	.7265250E+00	NODE 136
-.1223240E+01	.8173450E+00	NODE 137
-.1359155E+01	.9081600E+00	NODE 138
-.1495070E+01	.9989750E+00	NODE 139
-.1630985E+01	.1089790E+01	NODE 140
-.9238800E+00	.3826600E+00	NODE 141
-.1000870E+01	.4145700E+00	NODE 142
-.1077860E+01	.4464600E+00	NODE 143
-.1154850E+01	.4783500E+00	NODE 144
-.1231840E+01	.5102400E+00	NODE 145
-.1308830E+01	.5421350E+00	NODE 146
-.1385820E+01	.5740300E+00	NODE 147
-.1462810E+01	.6059200E+00	NODE 148
-.1539800E+01	.6378100E+00	NODE 149
-.1616790E+01	.6697000E+00	NODE 150
-.1693780E+01	.7015900E+00	NODE 151

-.1770770E+01	.7334800E+00	NODE 152
-.1847760E+01	.7653700E+00	NODE 153
-.9569400E+00	.2738400E+00	NODE 154
-.1116430E+01	.3057300E+00	NODE 155
-.1275920E+01	.3376200E+00	NODE 156
-.1435410E+01	.3695150E+00	NODE 157
-.1594900E+01	.4014050E+00	NODE 158
-.1754390E+01	.4332950E+00	NODE 159
-.1913681E+01	.4651850E+00	NODE 160
-.9900000E+00	.1650000E+00	NODE 161
-.1072500E+01	.1650000E+00	NODE 162
-.1155000E+01	.1650000E+00	NODE 163
-.1237500E+01	.1650000E+00	NODE 164
-.1320000E+01	.1650000E+00	NODE 165
-.1402500E+01	.1650000E+00	NODE 166
-.1485000E+01	.1650000E+00	NODE 167
-.1567500E+01	.1650000E+00	NODE 168
-.1650000E+01	.1650000E+00	NODE 169
-.1732500E+01	.1650000E+00	NODE 170
-.1815000E+01	.1650000E+00	NODE 171
-.1897500E+01	.1650000E+00	NODE 172
-.1930000E+01	.1650000E+00	NODE 173
-.3950000E+00	.8250000E-01	NODE 174
-.1160835E+01	.8250000E-01	NODE 175
-.1326665E+01	.8250000E-01	NODE 176
-.1658335E+01	.8250000E-01	NODE 177
-.1824165E+01	.8250000E-01	NODE 178
-.1990000E+01	.8250000E-01	NODE 179
-.1000000E+01	0.	NODE 180
-.1083335E+01	0.	NODE 181
-.1166670E+01	0.	NODE 182
-.1250000E+01	0.	NODE 183
-.1333330E+01	0.	NODE 184
-.1666670E+01	0.	NODE 185
-.1750000E+01	0.	NODE 186
-.1833330E+01	0.	NODE 187
-.1916665E+01	0.	NODE 188
-.2000000E+01	0.	NODE 189
-.1352500E+01	0.	NODE 190
-.1345835E+01	.1466650E+00	NODE 191
-.1492500E+01	.1466650E+00	NODE 192
-.1639165E+01	.1466650E+00	NODE 193
-.1647500E+01	0.	NODE 194
-.1371670E+01	0.	NODE 195
-.1371670E+01	.6416500E-01	NODE 196
-.1371670E+01	.1283300E+00	NODE 197
-.1435835E+01	.1283300E+00	NODE 198
-.1500000E+01	.1283300E+00	NODE 199
-.1564165E+01	.1283300E+00	NODE 200
-.1628330E+01	.1283300E+00	NODE 201
-.1628330E+01	.6416500E-01	NODE 202
-.1628330E+01	0.	NODE 203

-.1400420E+01	0.	NODE 204
-.1400420E+01	.9958000E-01	NODE 205
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-.1599580E+01	.9958000E-01	NODE 207
-.1599580E+01	0.	NODE 208
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-.1429170E+01	.3541500E-01	NODE 210
-.1429170E+01	.7083000E-01	NODE 211
-.1464585E+01	.7083000E-01	NODE 212
-.1500000E+01	.7083000E-01	NODE 213
-.1535415E+01	.7083000E-01	NODE 214
-.1570830E+01	.7083000E-01	NODE 215
-.1570830E+01	.3541500E-01	NODE 216
-.1570830E+01	0.	NODE 217
-.1438750E+01	0.	NODE 218
-.1438750E+01	.6125000E-01	NODE 219
-.1500000E+01	.6125000E-01	NODE 220
-.1561250E+01	.6125000E-01	NODE 221
-.1561250E+01	0.	NODE 222
-.1448330E+01	0.	NODE 223
-.1448330E+01	.2583500E-01	NODE 224
-.1448330E+01	.5167000E-01	NODE 225
-.1474165E+01	.5167000E-01	NODE 226
-.1500000E+01	.5167000E-01	NODE 227
-.1525835E+01	.5167000E-01	NODE 228
-.1551670E+01	.5167000E-01	NODE 229
-.1551670E+01	.2583500E-01	NODE 230
-.1551670E+01	0.	NODE 231
-.1460830E+01	0.	NODE 232
-.1460830E+01	.3917000E-01	NODE 233
-.1500000E+01	.3917000E-01	NODE 234
-.1539170E+01	.3917000E-01	NODE 235
-.1539170E+01	0.	NODE 236
-.1473330E+01	0.	NODE 237
-.1473330E+01	.1333500E-01	NODE 238
-.1473330E+01	.2667000E-01	NODE 239
-.1486665E+01	.2667000E-01	NODE 240
-.1500000E+01	.2667000E-01	NODE 241
-.1513335E+01	.2667000E-01	NODE 242
-.1526670E+01	.2667000E-01	NODE 243
-.1526670E+01	.1333500E-01	NODE 244
-.1526670E+01	0.	NODE 245
-.1481665E+01	0.	NODE 246
-.1483130E+01	.1687000E-01	NODE 247
-.1500000E+01	.1833500E-01	NODE 248
-.1516870E+01	.1687000E-01	NODE 249
-.1518335E+01	0.	NODE 250
-.1490000E+01	0.	NODE 251
-.1491465E+01	.3535000E-02	NODE 252
-.1492930E+01	.7070000E-02	NODE 253
-.1496465E+01	.8535000E-02	NODE 254
-.1500000E+01	.1000000E-01	NODE 255

-.1503535E+01	.8535000E-02	NODE256
-.15[illegible]7[illegible]7[illegible]E+[illegible]1	.7[illegible]7[illegible]E-02	NODE257
-.1506535E+01	.3535000E-02	NODE258
-.1510000E+01	0.	NODE259
-.1437500E+01	0.	NODE260
-.1496230E+01	.177[illegible]E-[illegible]2	NODE261
-.1500000E+01	.2500000E-02	NODE262
-.1501770E+01	.1770000E-02	NODE263
-.1502500E+01	0.	NODE264
-.1500000E+01	0.	NODE265
-.15[illegible]E+[illegible]1	[illegible].	NODE266
-.1500000E+01	0.	NODE267

The execution of SRL01A resulted in the following values for stress intensity factor, crack opening displacement, and load point displacement:

K_I = 1.8940 psi$\sqrt{in}$

COD = 2 × (Y-displacement of node 180) = 6.45932 × 10^{-7} in.

$\delta_{L.P}$ = sum of the absolute value of X - displacements of node 189 and node 13 = 15.31517 × 10^{-7} in.

SECTION VI
CONCLUSION

The report contains user's manuals for the following programs:

1. SRL01A: A two dimensional linear elastic finite element analysis code for crack problems.
2. SRL11: A mesh plotting program.
3. SRLC: A mesh generation program for C-shaped and double-notch ring shaped specimens.
4. SRLRNG: A mesh generation program for single-notch ring shaped specimens.
5. SRLCMP: A mesh generation program for compact tension type specimen geometries.
6. SRLBND: A mesh generation program for bend specimen geometry.

Although the mesh generation programs have been carefully tested, the user should not expect these programs to produce acceptable data for arbitrarily chosen geometrical dimensions for any given specimen shape. The programs are however expected to generate proper data for standard geometries with minor modifications.

It is highly recommended that a new user try to solve one or more of the illustrative examples presented in Section IV before attempting to solve a new problem.

APPENDIX I

MESH GENERATING PROGRAMS

1. C-SHAPED SPECIMEN

The finite element data for SRL01A to analyze a C-shaped specimen may be generated by executing the following program:

```
Job Card
ATTACH,LGO,SRLC,ID=M760328.
ATTACH,TAPE8,SRLC1,ID=M760328.
LGO.
End-of-record
N (Total number of data sets to be generated minus 1)
A RI RO  (Crack length, inner radius, outer radius)
.
.
.
.
.
A RI RO
End-of-job.
```

Note:
a) Format for N is (I4)
b) Format for A, RI, RO is (3F10.5)
c) The mesh may also be used to analyze double notch circular ring specimens (see examples 2 and 3).

2. SINGLE-NOTCH RING SPECIMEN

Data for a single notch ring specimen (Fig. 15a) can be generated by using the following program.

```
Job Card
ATTACH,LGO,SRLRNG,ID=M760328.
ATTACH,TAPE8,SRLRG,CY=2,ID=M760328.
LGO.
End-of-record
A  RI  RO  (crack length, inner radius, outer radius)
End-of-job.
```

Note: a) Format for the data card is (3F10.5)

b) For multiple runs put as many LGO. cards as number of cases, and place an end-of-record card in front of each data card.

c) The mesh may also be used for a single notch ring tension specimen (Fig. 15b) simply by changing the location of the applied load from nodes 13 and 189 to node 81.

3. COMPACT TYPE SPECIMEN

The data to analyze a compact specimen of given geometry may be generated by using the following program.

```
Job Card
ATTACH,LGO,SRLCMP,ID=M760328.
ATTACH,TAPE8,SRLCM,CY=2,ID=M760328.
LGO.
End-of-record
A  E  F  H  S  THETA  W  W1  R  GS
End-of-job
```

Note: a) Format for the data card (10F7.4)

b) GS is the distance n-n in Fig. 11.

c) Procedure for multiple runs is the same as for single notch ring specimen of the previous section.

4. THREE POINT BEND SPECIMEN

```
Job Card
ATTACH,LGO,SRLBND,ID=M760328.
ATTACH,TAPE8,SRLB,CY=2,ID=M760328.
LGO.
End-of-record
L   S   W   G'  N   P'  THETA   G   A   H   B
End-of-job
```

Note: a) Format for the data card (11F7.4) for definition of symbols see Fig. 14.

b) For multiple runs follow the procedure described in Section 3 for single notch ring specimen.

APPENDIX II

PLOTTING PROGRAM

1. USER'S GUIDE FOR MESH PLOTTING PROGRAM (SRL11)

a. Data Set 1, Format (3I4), Number of cards = 1

Columns	Variable/Constant	Definition
4	6	Output unit
5-8	NPOIN	Total number of nodes*
9-12	NELEM	Total number of elements*

*See a. Section III.

b. Data Set 2*, Form (I4,2F10·5), Number of cards = NCPOIN**

Columns	Variable	Definition
1-4	I	Node number of corner point
5-14	X(I)	Y-coordinate of I
15-24	Y(I)	Y-coordinate of I

*Use the same data cards as 5. Section II.

**See a. Section III.

c. Data Set 3, Format (not applicable), Number of cards = 1

(Blank Data Card)

d. Data Set 4, Format (8I4), Number of cards = NELEM*

Columns	Variable	Definition
1-4	I	Element connectivities. Use Data Set 6 of f., Section III.
5-8	I + 1	Element connectivities. Use Data Set 6 of f., Section III.
9-12	I + 2	Element connectivities. Use Data Set 6 of f., Section III.
13-16	I + 3	Element connectivities. Use Data Set 6 of f., Section III.
17-20	I + 4	Element connectivities. Use Data Set 6 of f., Section III.
21-24	I + 5	Element connectivities. Use Data Set 6 of f., Section III.
25-28	I + 6	Element connectivities. Use Data Set 6 of f., Section III.
29-32	I + 7	Element connectivities. Use Data Set 6 of f., Section III.

*See a. Section III.

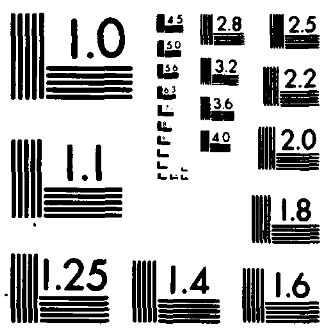
e. Data Set 5, Format (3I5,A10), Number of cards = 1

Columns	Variable/Constant	Definition
5	1	
6-10	12	
11-15	L	Output parameter
16-25	LABEL	MESH TITLE

AD-A087 440 SYSTEMS RESEARCH LABS INC DAYTON OHIO F/6 9/2
TWO DIMENSIONAL LINEAR ELASTIC ANALYSIS OF FRACTURE SPECIMENS U--ETC(U)
FEB 80 J AHMAD F33615-79-C-5025
UNCLASSIFIED AFWAL-TR-80-4008 NL

2 of 2

END
DATE
FILMED
9-80
DTIC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU

Instructions

L	Give 1 if elements and nodes are not to be numbered.
	Give 2 if only elements are to be numbered.
	Give 3 if nodes and elements are to be numbered.
	Give 4 if only nodes are to be numbered.
LABEL	Give ten character title (including spaces, such as RING SPMN1).

NOTE: Only the corner nodes of the mesh are numbered by the program.

f. Data Set 6, Format (8F10·5), Number of cards = 1

Columns	Variable/Constant	Definition
1-10	YMIN	Minimum of Y-coordinates of all nodes
11-20	YMAX	Maximum of Y-coordinates of all nodes
21-30	XMIN	Minimum of X-coordinate of all nodes
31-40	XMAX	Maximum of X-coordinates of all nodes
41-50	YSCALE	Scale on the Y axis*
51-60	XSCALE	Scale on the X axis*
61-70	1·0	
71-80	1·0	

*It is recommended to use SCALE = YSCALE = Plot dimension desired divided by actual mesh dimension. Plot dimension desired is limited by the size of the paper available at CALCOMP plotter. Usually, Y dimension of the plot = (YMAX - YMIN) × YSCALE should not exceed 8 inches.

g. Data Set 7, Format (not applicable), Number of cards = 1

(Blank Data Card)

2. SAMPLE JOB SET-UP FOR THE BEAM PROBLEM OF SECTION II, 5.

```
AAA,CM150000,T100,I0100,STANY. M760328
ATTACH,CCAUX,CCAUX,ID=LIBRARY,SN=ASD
LIBRARY,CCAUX.
ATTACH,LGO,SRL11,ID=M760328.
LGO.
End-of-record card.

    6       18       3
    1        4.0     0.5
    3        4.0     1.5
    6        3.5     0.5
    8        3.5     1.5
   11        1.5     0.5
   13        1.5     1.5
   16        0.5     0.5
   18        0.5     1.5

BLANK CARD
    1        3        8        6        2        5        7        4
    8       13       11        6       10       12        9        7
   16       11       13       18       14       12       15       17
        1       12        3       BEAM
    0.5      1.5      1.0      .0       2.0      2.0      1.0      1.0
      BLANK CARD
    End-of-data card
```

REFERENCES

1. K. J. Bathe and E. L. Wilson, Numerical Methods in Finite Element Analysis, Prentice-Hall, 1976.

2. S. R. Barsoum, On the Use of Isoparametric Finite Elements in Linear Fracture Mechanics, Int. J. Num. Meth. in Engrg., 10 (1), 1976.

3. N. E. Ashbaugh and J. Ahmad, paper submitted to the Int. J. of Solids and Structures.

4. N. E. Ashbaugh, Mechanical Property Testing and Materials Evaluation and Modeling, AFML-TR-79-4127, Air Force Materials Laboratories, Wright Patterson Air Force Base, OH, 1979.

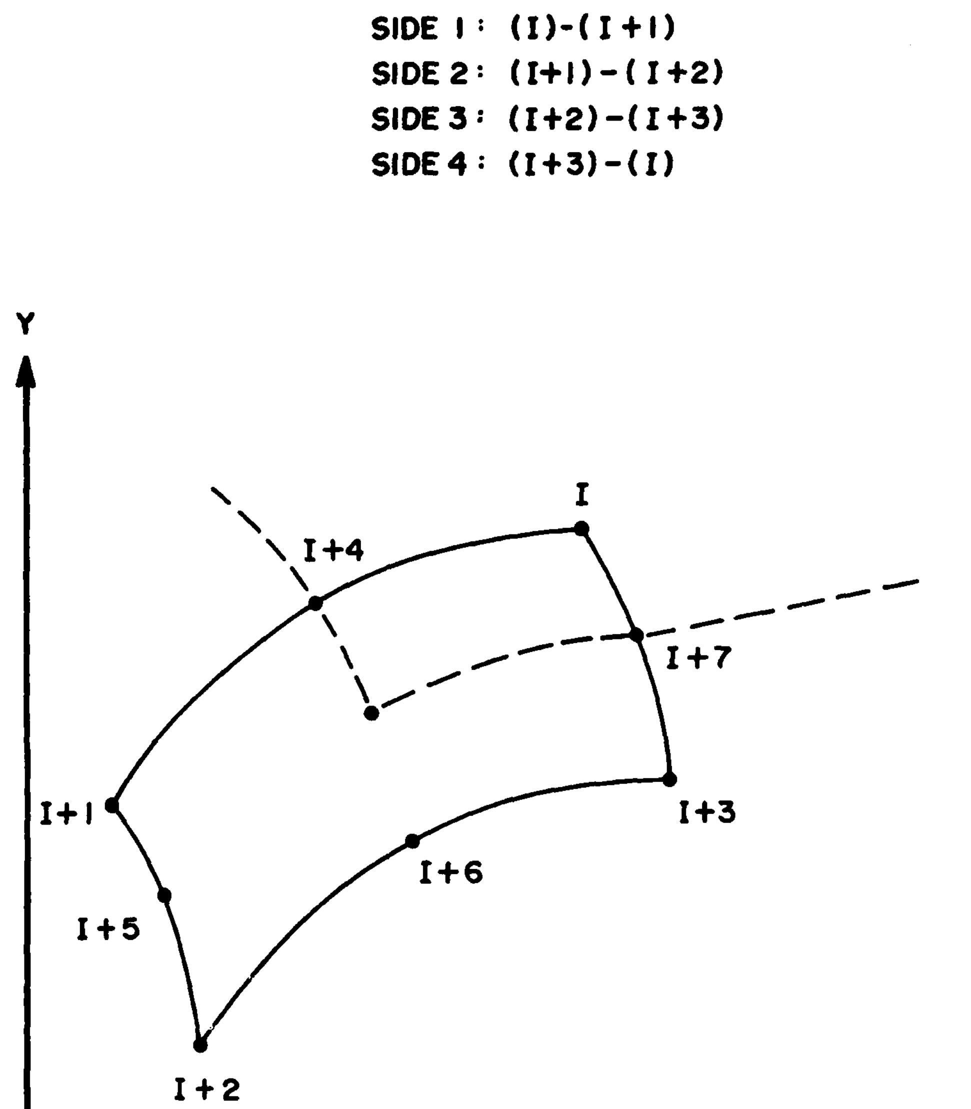


Figure 1. Eight Noded Quatrilateral Element.

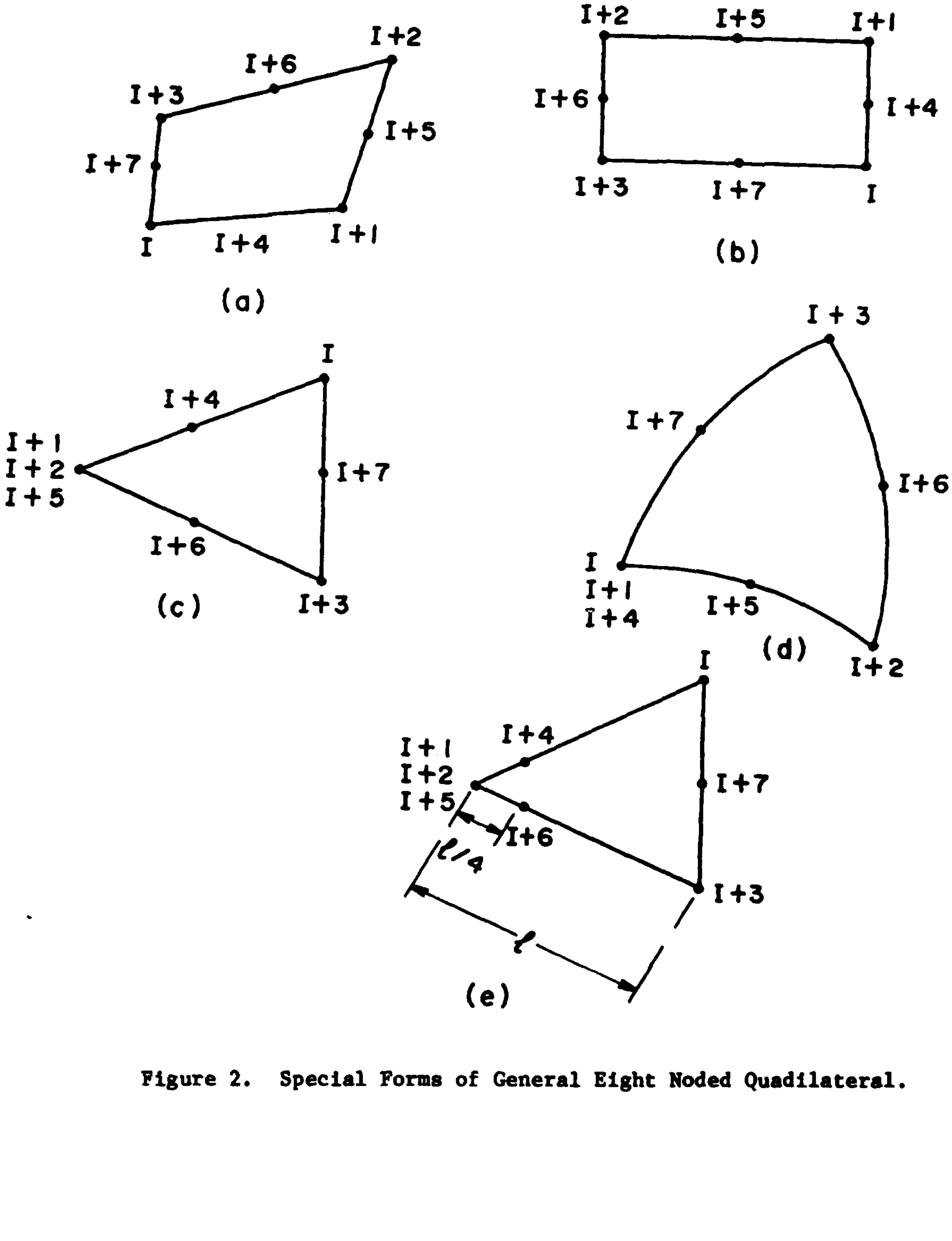


Figure 2. Special Forms of General Eight Noded Quadilateral.

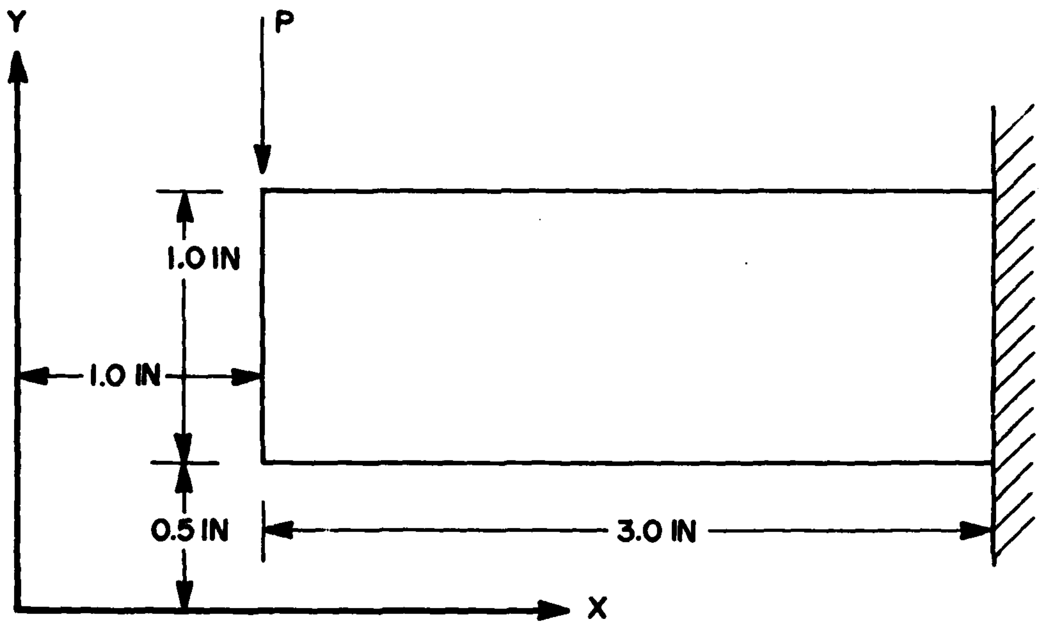


Figure 3. Cantilever Beam.

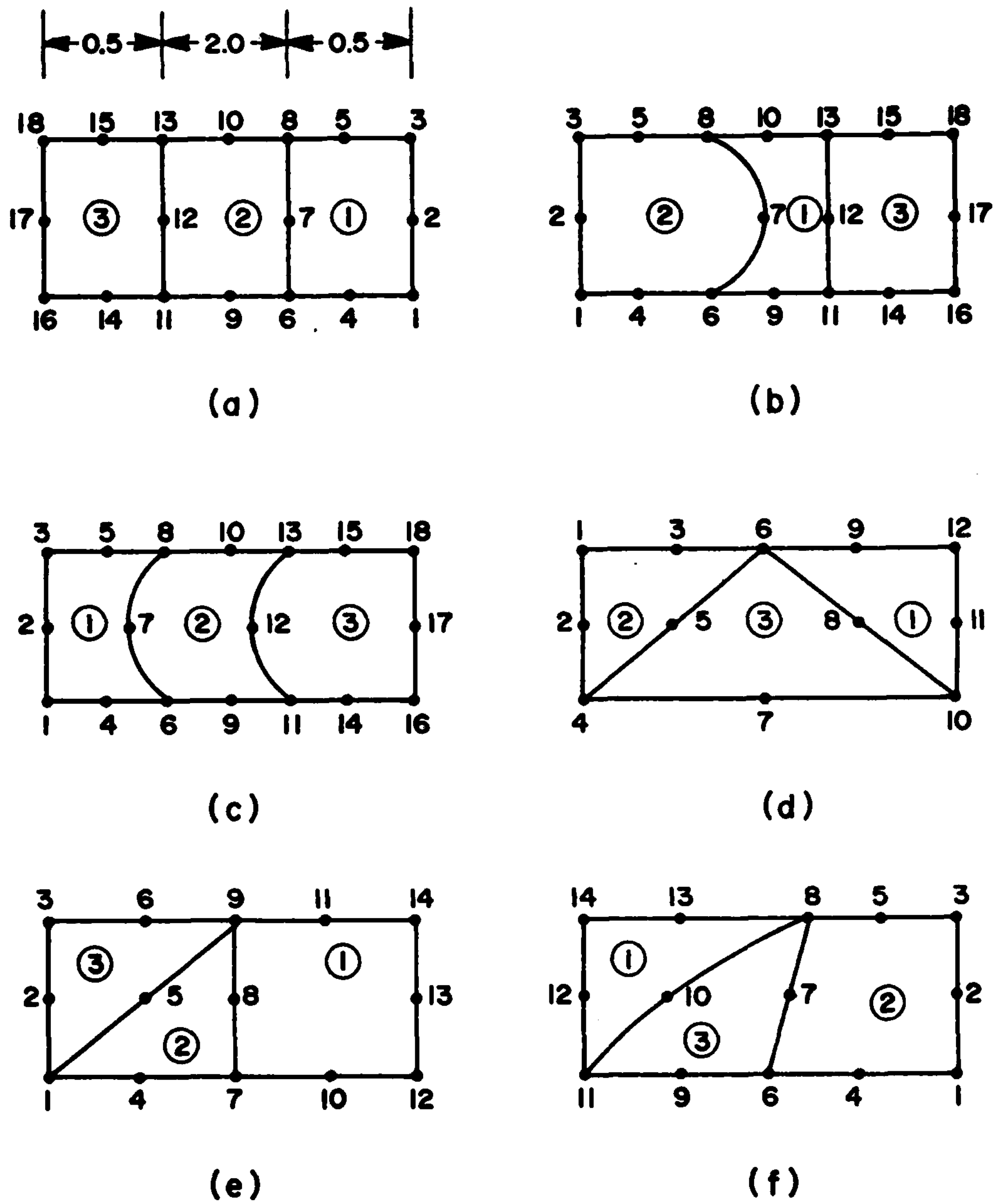


Figure 4. Some Possible Discretizations.

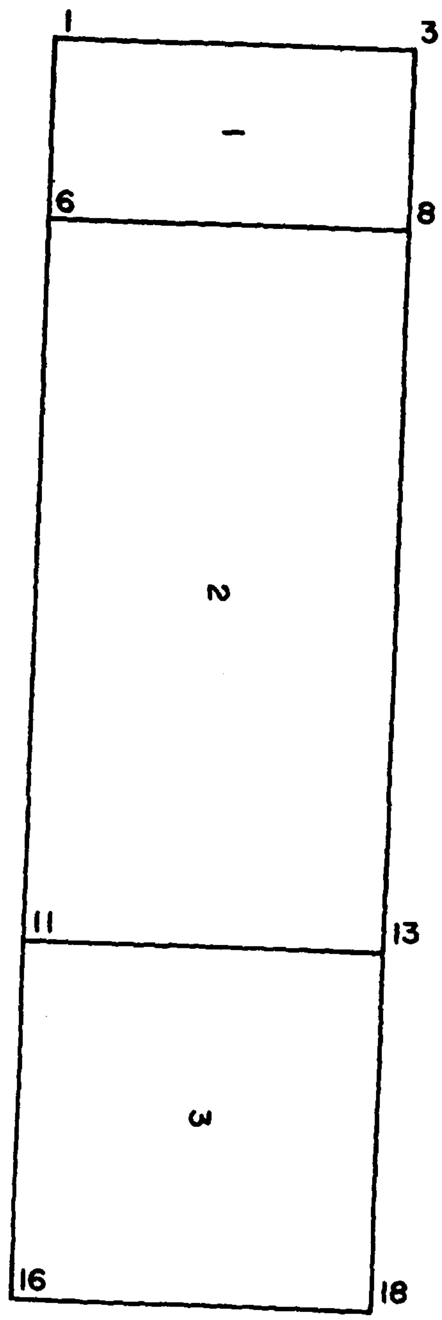


Figure 5. Mesh Plotted by SRL11. (Beam)

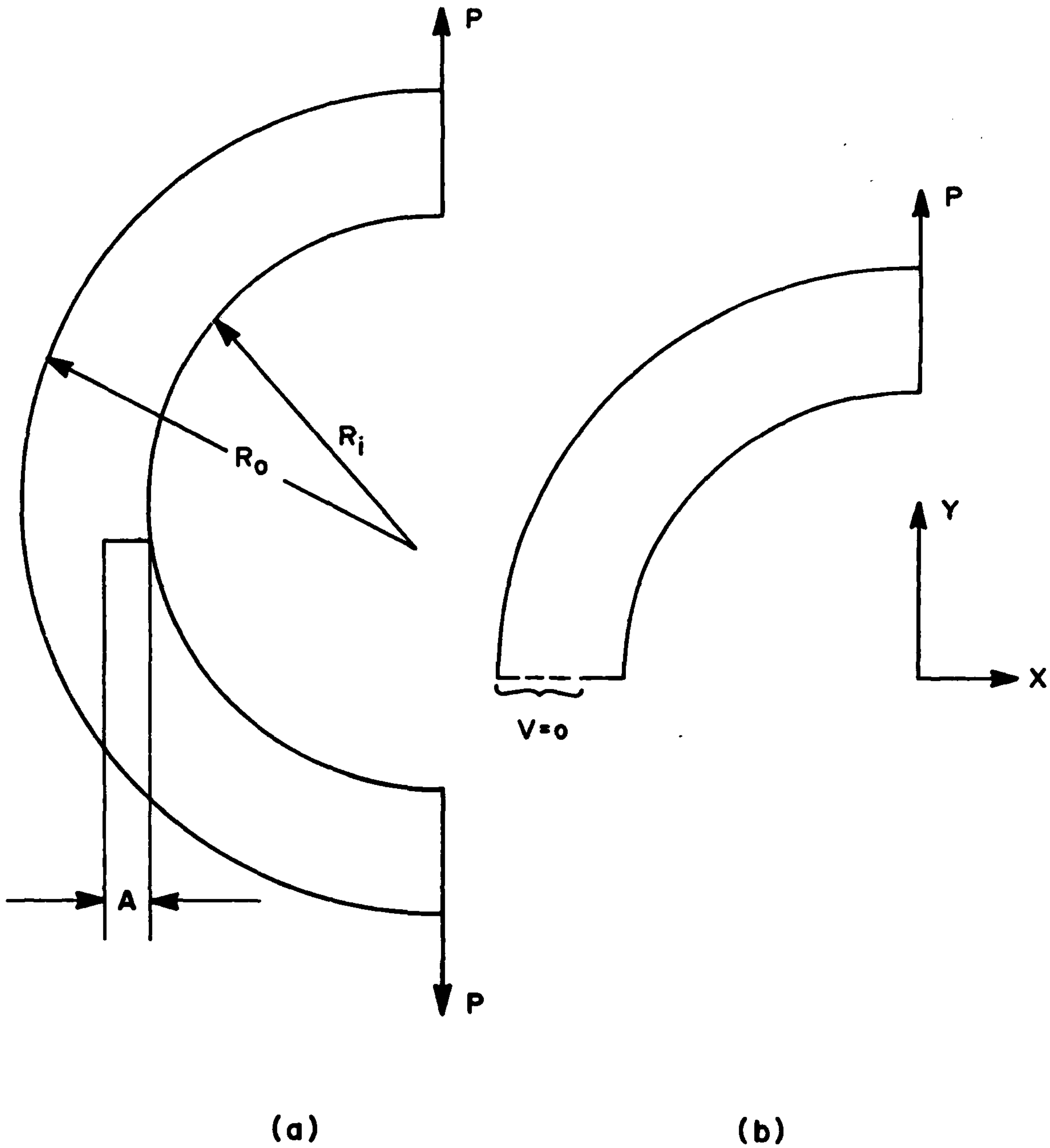


Figure 6. (a) Semi-Circular Cracked Ring.
(b) Region Needed for Analysis.

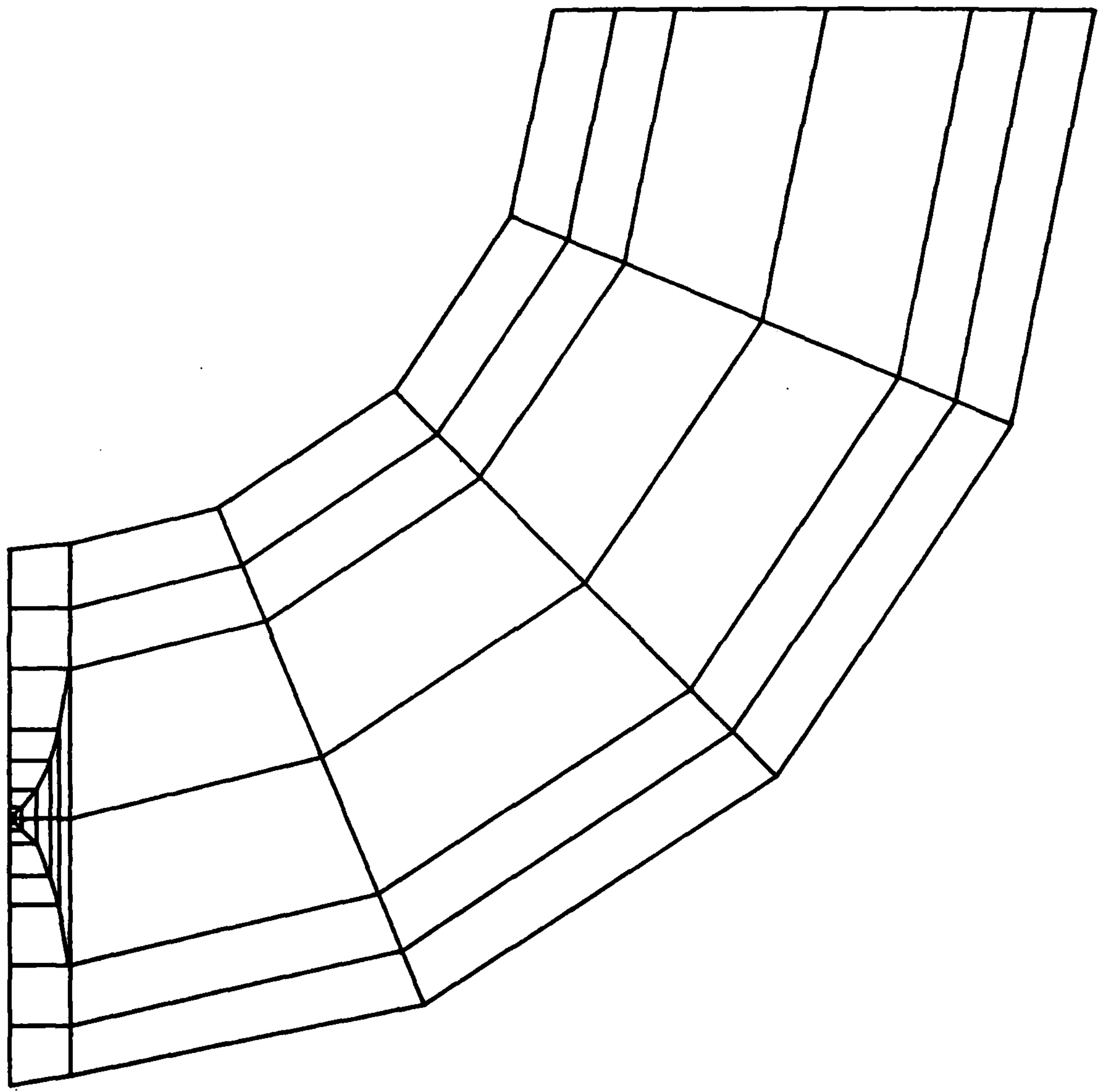


Figure 7. Mesh for C-Specimen.

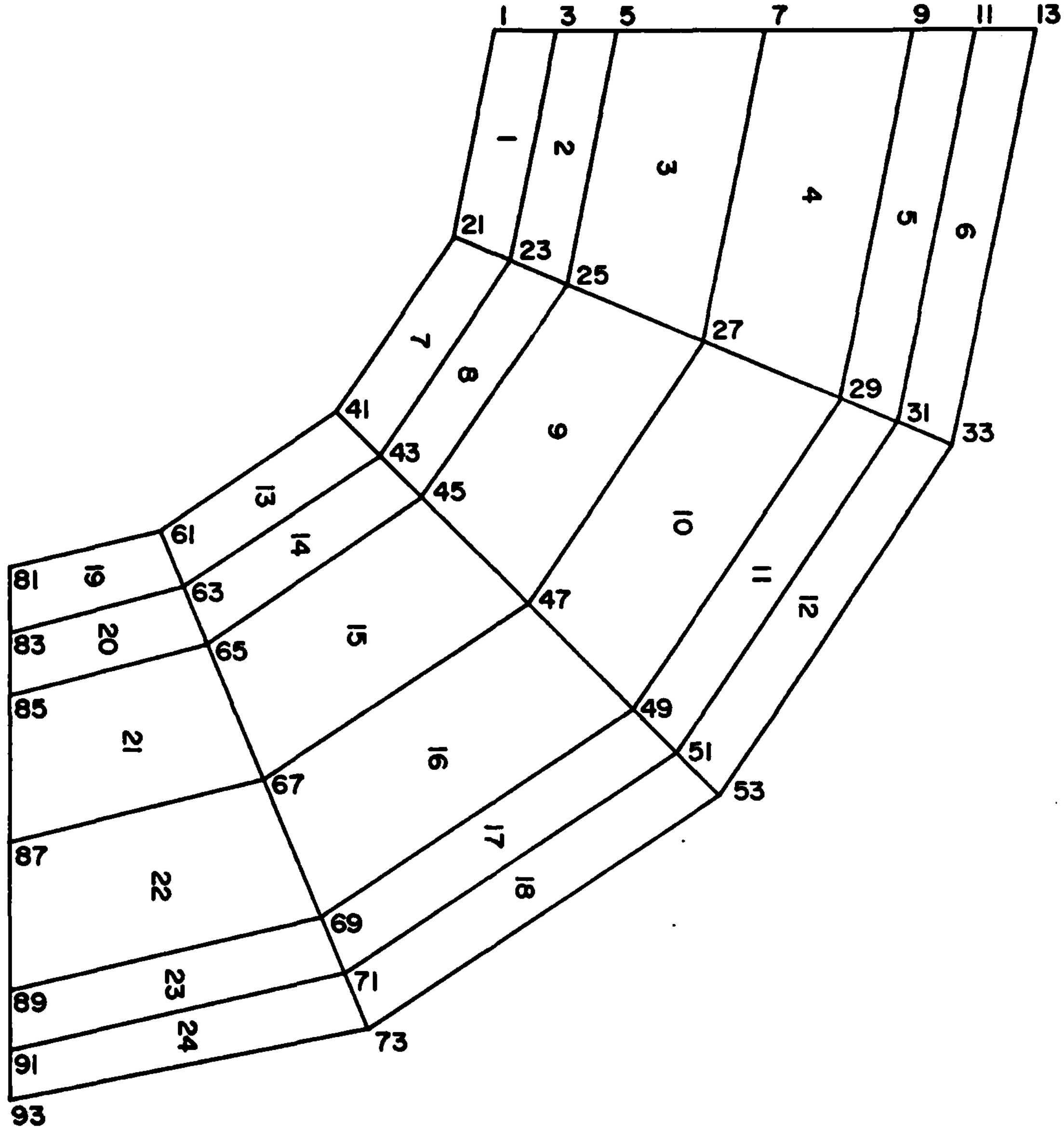


Figure 8. C-Specimen Mesh Details (a) Region Away from Crack Tip.

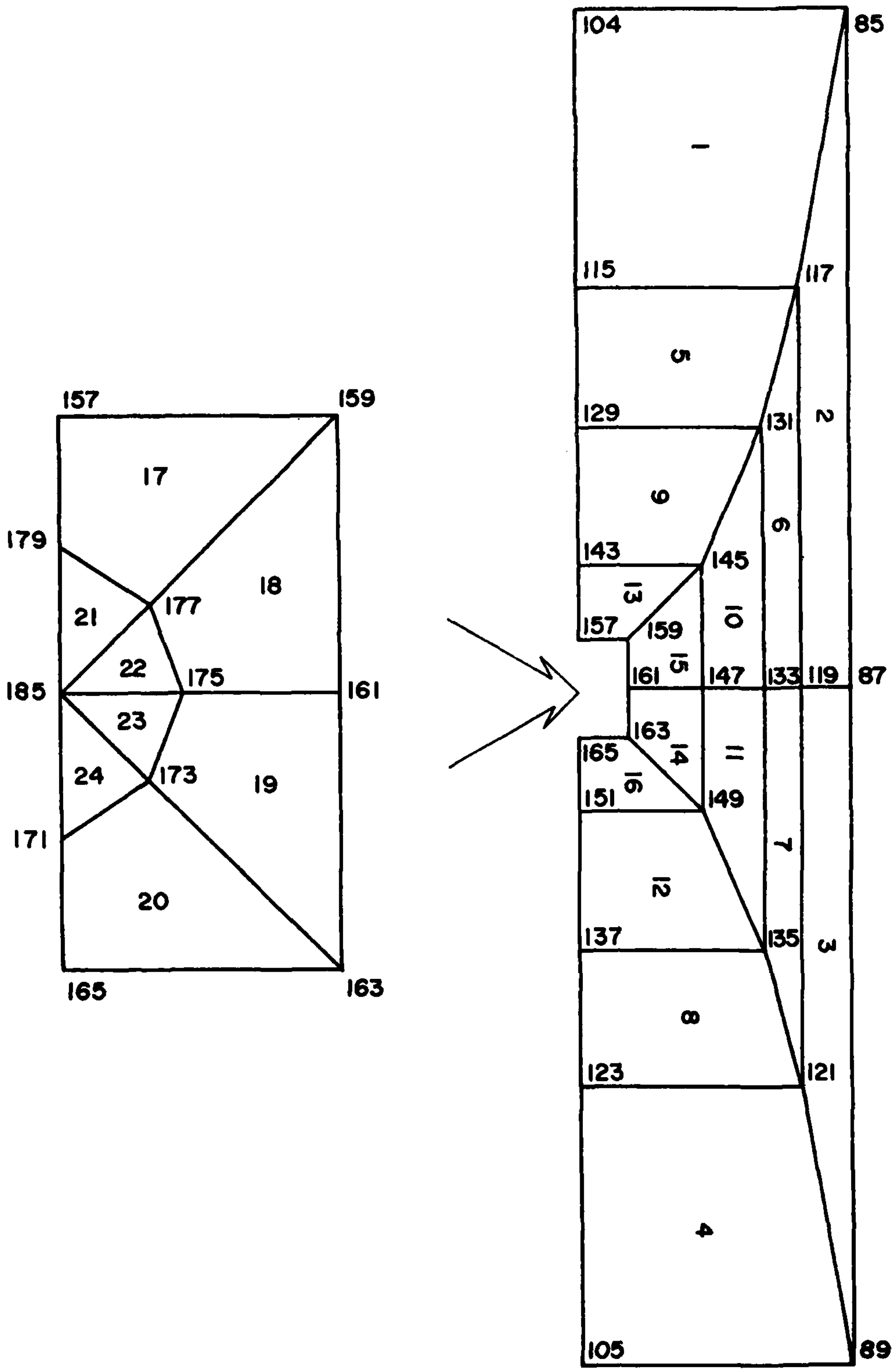
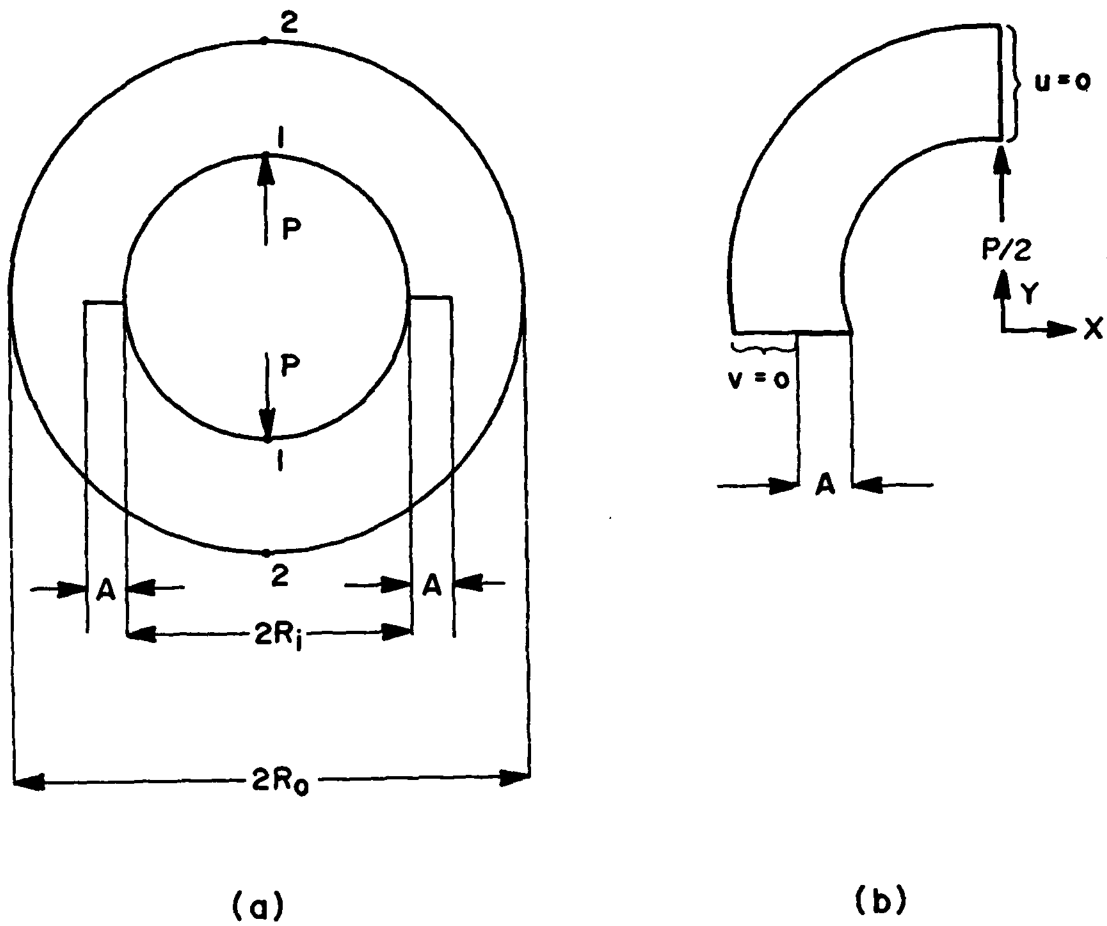


Figure 8. C-Specimen Mesh Details (b) Details of Near Crack Tip Region.



R_i = 1.0 IN.
R_o = 2.0 IN.
A = 0.5 IN.

Figure 9. (a) Double Notch Ring in Tension.

(b) One Quarter of the Ring with Displacement Boundary Conditions.

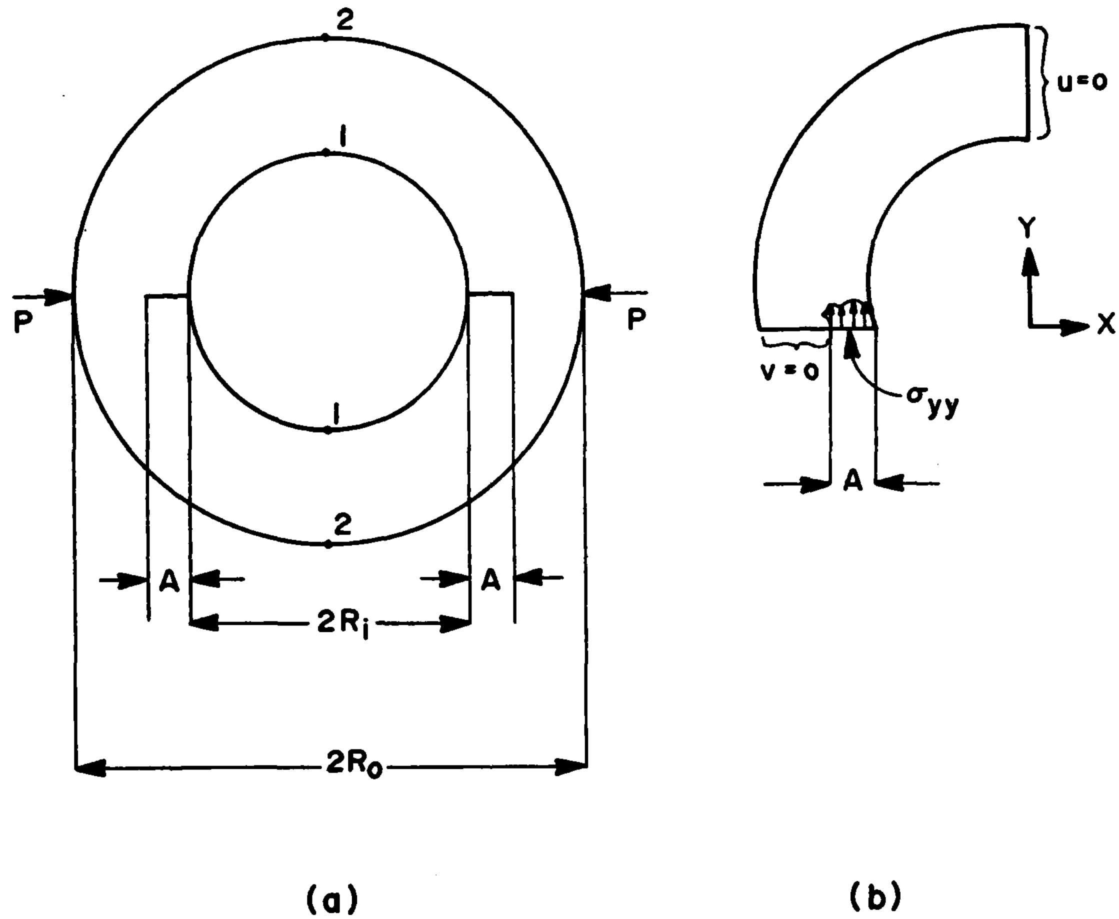


Figure 10. (a) Double Notch Ring in Compression.

(b) One Quarter of the Ring with Crack Line Pressure and Displacement Boundary Conditions.

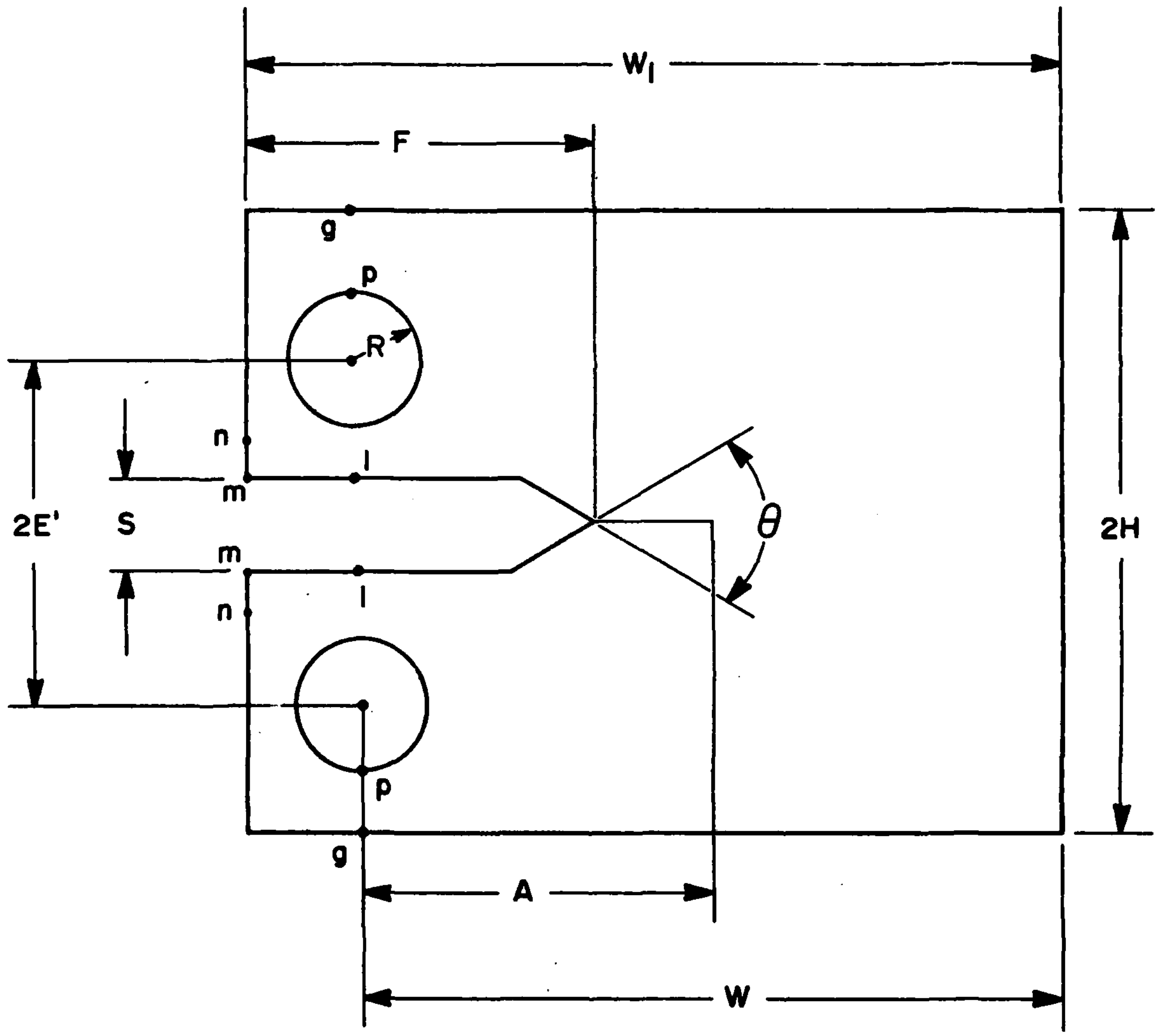


Figure 11. Compact Specimen. (Schematic)

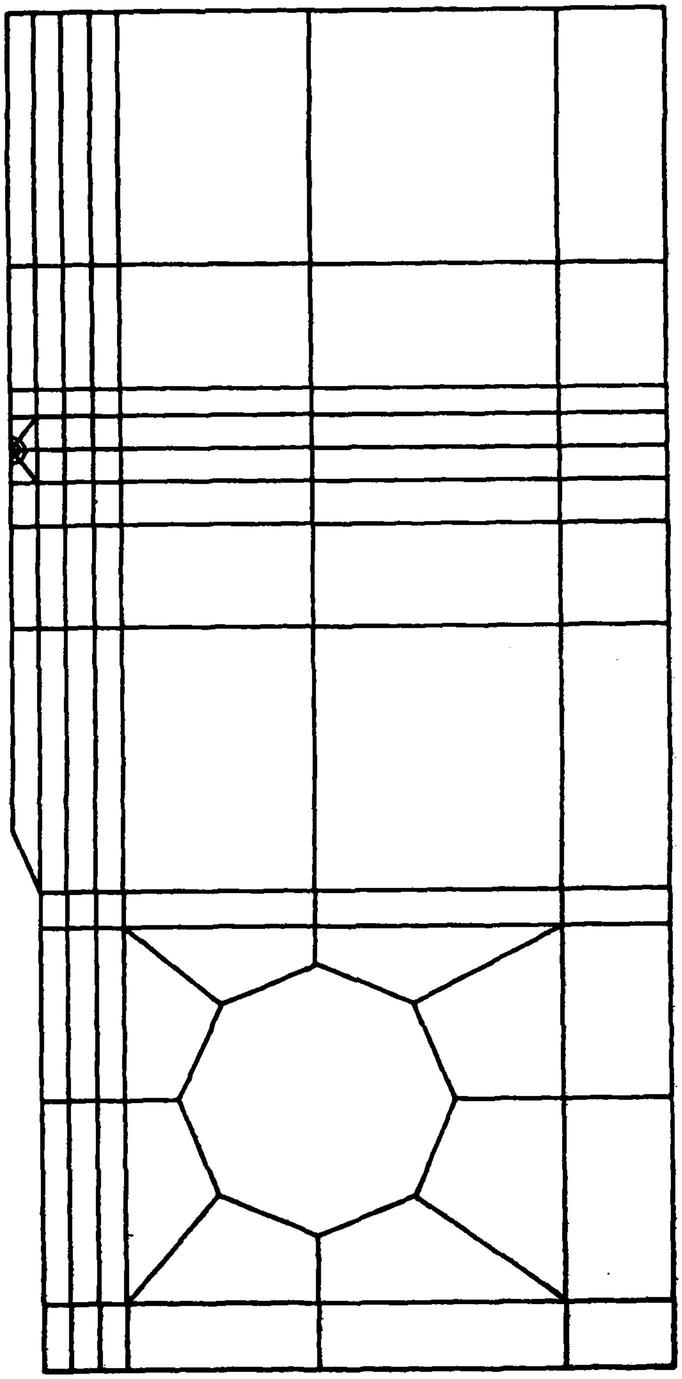


Figure 12 (a). Mesh for Compact Specimen.
Upper Half of Specimen.

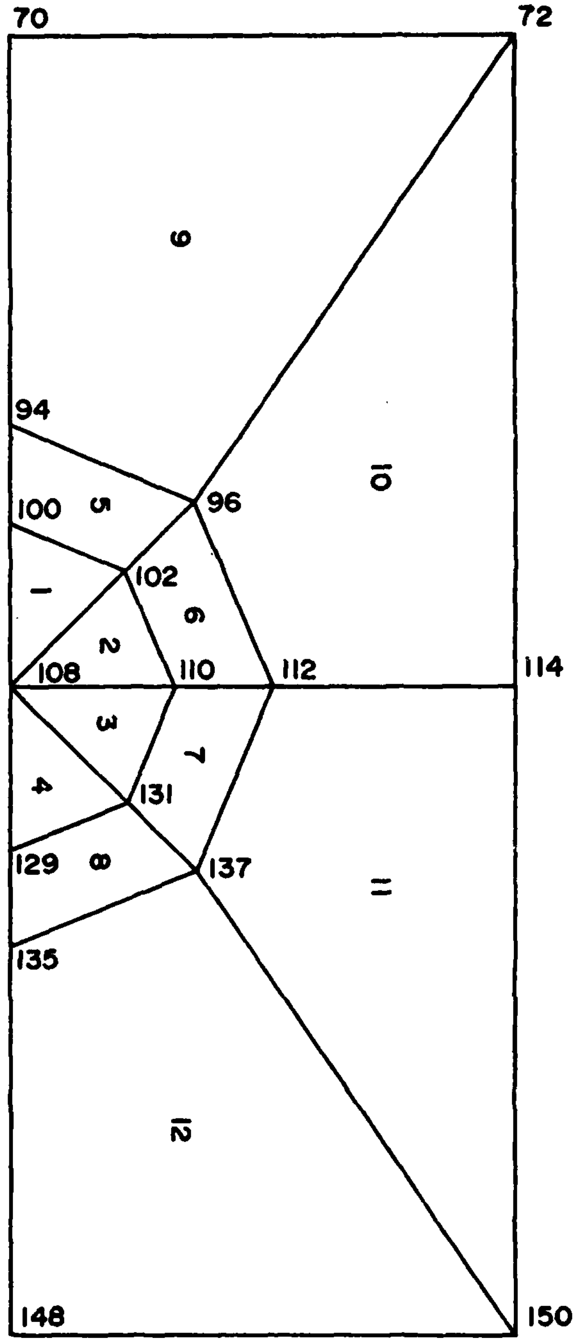


Figure 12 (b). Mesh for Compact Specimen.
Details of Crack-Tip Region.

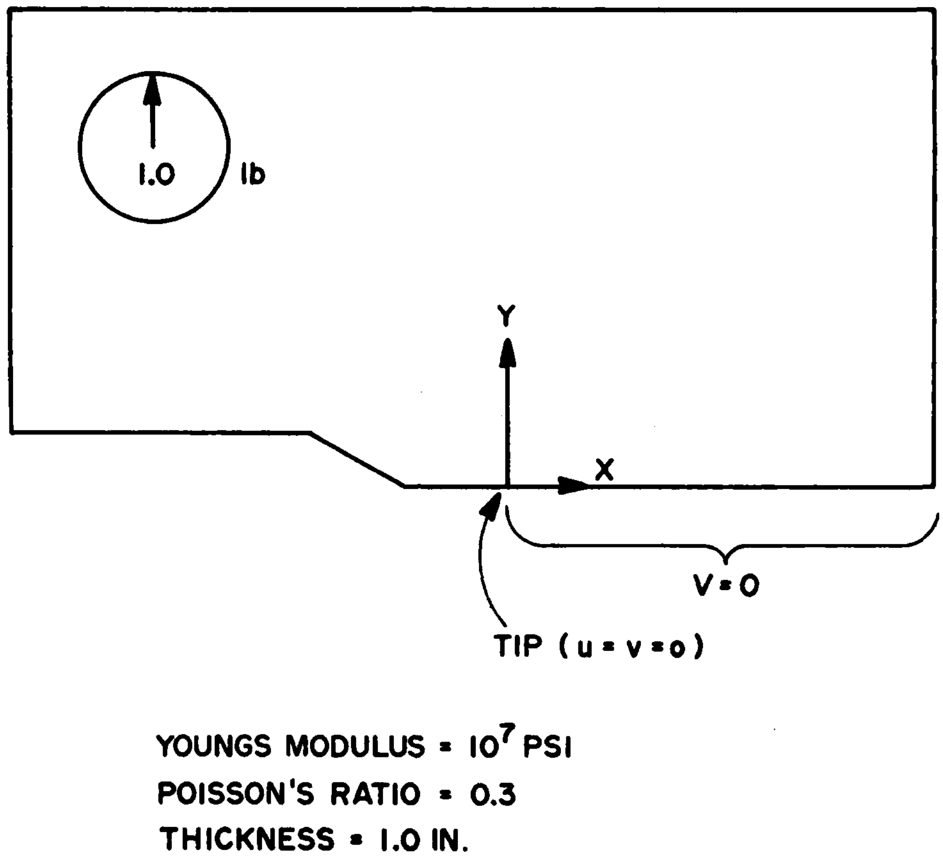


Figure 13. Upper Half of Compact Specimen. (Schematic)

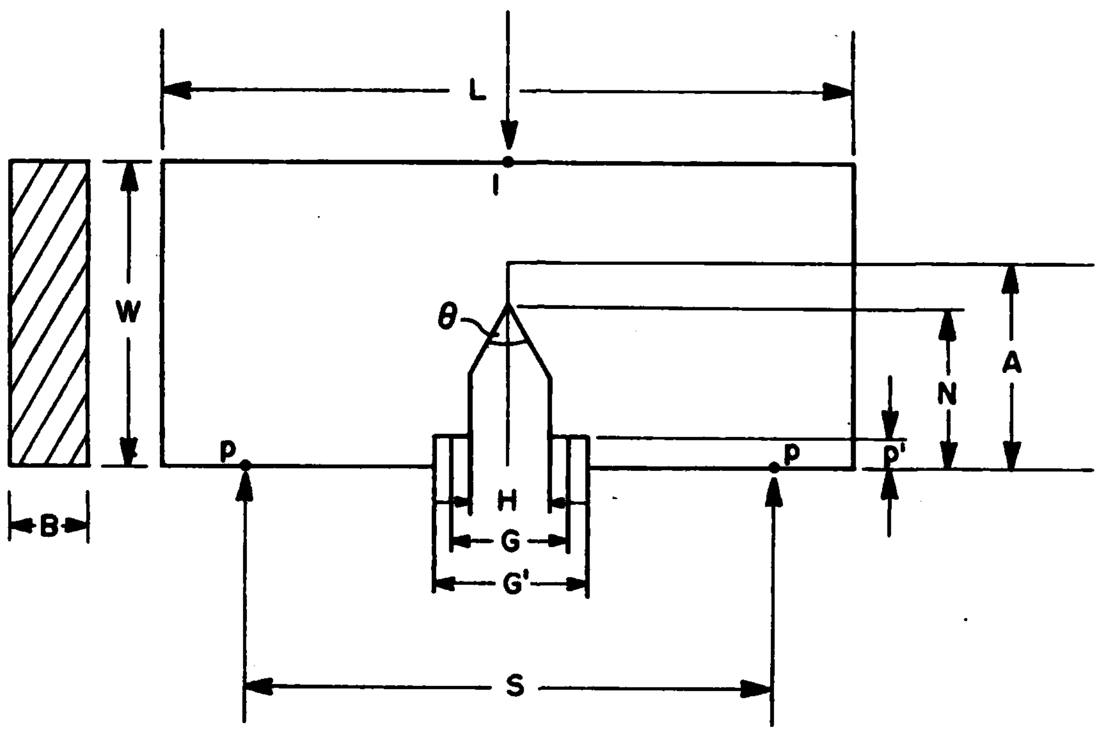


Figure 14. A Three Point Bend Specimen, (Schematic)

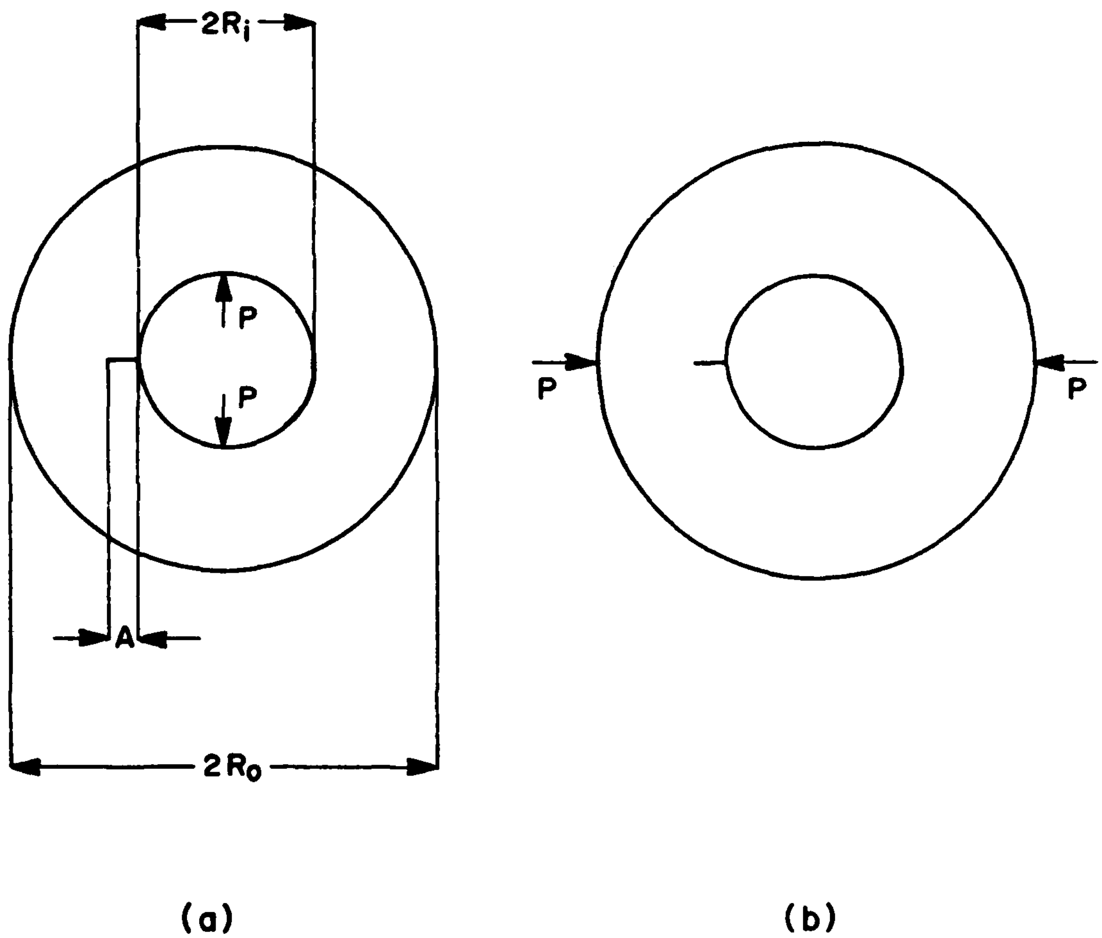


Figure 15. Single Notch Ring Specimens.

(a) Tension

(b) Compression

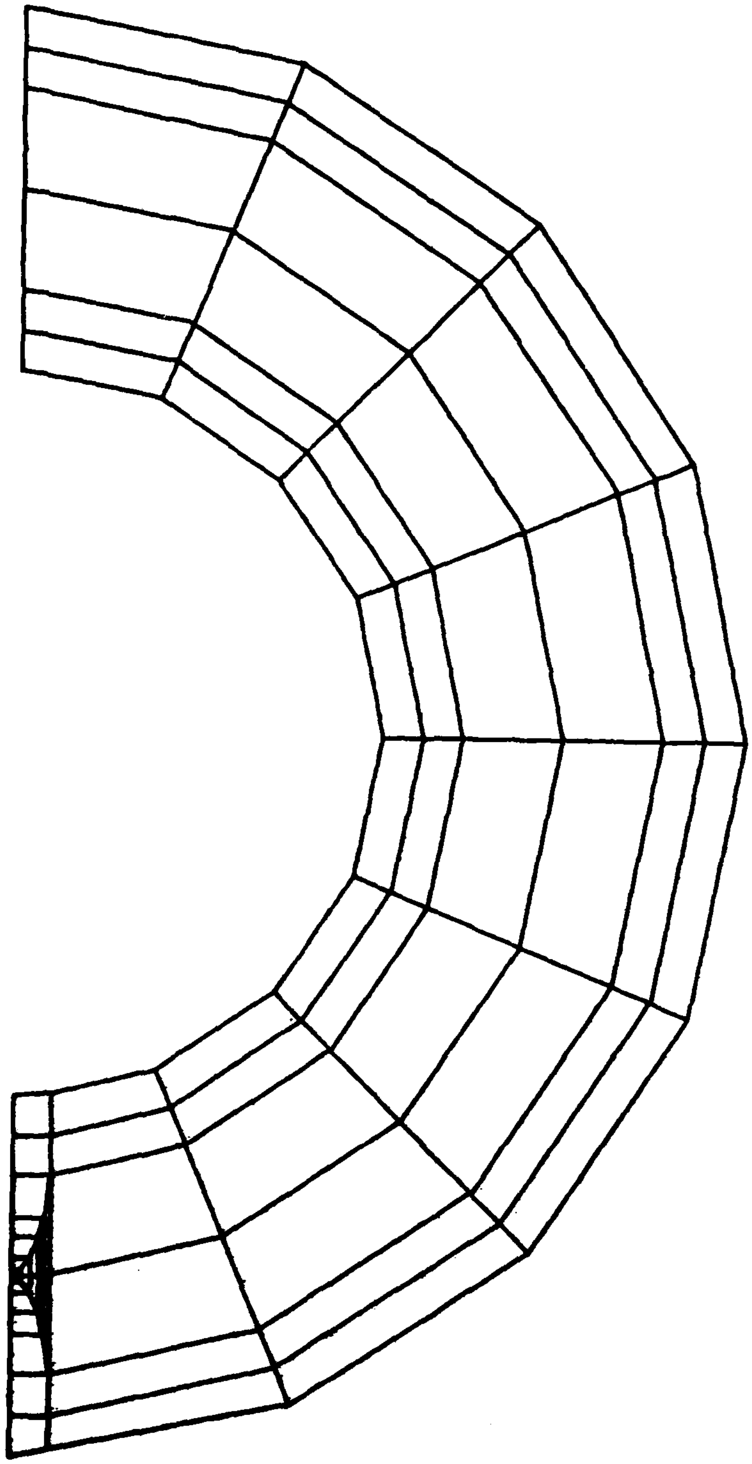


Figure 16. Mesh for Single Notch Ring Specimen.

*U.S.Government Printing Office: 1980 — 657-084/791