NASA TECHNICAL MEMORANDUM

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LaRC DESIGN ANALYSIS REPORT

FOR

NATIONAL TRANSONIC FACILITY

FOR

9% NICKEL TUNNEL SHELL

FINITE ELEMENT ANALYSIS OF PLENUM REGION INCLUDING SIDE ACCESS REINFORCEMENT, SIDE ACCESS DOOR AND ANGLE OF ATTACK PENETRATION

VOL. 3

BY

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16. Abstract This report contains the results of extensive computer (finite element, finite difference and numerical integration), thermal, fatigue, and special analyses of critical portions of a large pressurized, cryogenic wind tunnel (National Transonic Facility). The computer models, loading and boundary conditions are described. Graphic capability was used to display model geometry, section properties, and stress results. A stress criteria is presented for evaluation of the results of the analyses. Thermal analyses were performed for major critical and typical areas. Fatigue analyses of the entire tunnel circuit is presented.

The major computer codes utilized are: SPAR - developed by Engineering Information Systems, Inc. under NASA Contracts NAS8-30536 and NAS1-13977; SALORS - developed by Langley Research Center and described in NASA TN D-7179; and SRA - developed by Structures Research Associates under NASA Contract NAS1-10091; "A General Transient Heat-Transfer Computer Program for Thermally Thick Walls" developed by Langley Research Center and described in NASA TM X-2058.

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NTF TUNNEL SHELL

NASA LaRC

FINITE ELEMENT ANALYSIS
OF
PLENUM REGION INCLUDING
SIDE ACCESS REINFORCEMENT,
SIDE ACCESS DOOR AND ANGLE OF
ATTACK PENETRATION

9% Ni

SEPTEMBER 1976

VOLUME 3

LaRC CALCULATIONS

FOR THE

NATIONAL TRANSONIC FACILITY

TUNNEL SHELL

DATE: SEPTEMBER, 1976

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This report is one volume of a Design Analysis Report prepared by LaRC on portions of the pressure shell for the National Transonic Facility. This report is to be used in conjunction with reports prepared under NASA Contract NAS1-13535(c) by the Ralph M. Parsons Company (Job Number 5409-3 dated September 1976) and Fluidyne Engineering Corporation (Job Number 1060 dated September 1976). The volumes prepared by LaRC are listed below:

1. Finite Difference Analysis of Cone/Cylinder (9% Ni), Vol. 1, NASA TM X73956-1.

2. Finite Element Analysis of Corners #3 and #4 (9% Ni), Vol. 2, NASA TM X73956-2.

3. Finite Element Analysis of Plenum Region Including Side Access Reinforcement, Side Access Door and Angle of Attack Penetration (9% Ni), Vol. 3, NASA TM X73956-3.

4. Thermal Analysis (9% Ni), Vol. 4, NASA TM X73956-4.

5. Finite Element and Numerical Integration Analyses of the Bulkhead Region (9% Ni), Vol. 5, NASA TM X73956-5.

6. Fatigue Analysis (9% Ni), Vol. 6, NASA TM X73956-6.

7. Special Studies (9% Ni), Vol. 7, NASA TM X73956-7.

NTF DESIGN CRITERIA
FOR 9% NICKEL

GENERAL

THE DESIGN OF THE PRESSURE SHELL REFLECTED IN THIS REPORT SATISFIES THE DESIGN REQUIREMENTS OF THE ASME BOILER AND PRESSURE VESSEL CODE, SECTION VIII, DIVISION 1. SINCE DIVISION 1 DOES NOT CONTAIN RULES TO COVER ALL DETAILS OF DESIGN, ADDITIONAL ANALYSES WERE PERFORMED IN AREAS HAVING COMPLEX CONFIGURATIONS SUCH AS THE CONE CYLINDER JUNCTIONS, THE GATE VALVE BULKHEADS, THE BULKHEAD-SHELL ATTACHMENTS, THE PLENUM ACCESS DOORS AND REINFORCEMENT AREAS, THE ELLIPTICAL CORNER SECTIONS, AND THE FIXED REGION (RING S8) OF THE TUNNEL. THE DIVISION 1 DESIGN CALCULATIONS, THE ADDITIONAL ANALYSES AND THE CRITERIA FOR EVALUATION OF THE RESULTS OF THE ADDITIONAL ANALYSES TO ENSURE COMPLIANCE WITH THE INTENT OF DIVISION 1 REQUIREMENTS ARE CONTAINED IN THE TEXT OF THIS REPORT. THE DESIGN ANALYSES AND ASSOCIATED CRITERIA CONSIDERED BOTH THE OPERATING AND HYDROSTATIC TEST CONDITIONS.

IN CONJUNCTION WITH THE DESIGN, A DETAILED FATIGUE ANALYSIS OF THE PRESSURE SHELL WAS ALSO PERFORMED UTILIZING THE METHODS OF THE ASME CODE, SECTION VIII, DIVISION 2.

MATERIAL

THE PRESSURE SHELL MATERIAL SHALL BE ASME, SA-553-1 FOR PLATE AND SA-522 FOR FORGINGS. THE MATERIAL PROPERTIES AT TEMPERATURES EQUAL TO OR BELOW 150°F ARE AS FOLLOWS:

(A) PLATE, 2.0 INCHES OR THINNER

YIELD = 85.0 KSI
ULTIMATE = 100 KSI

(B) WELDS (AUTOMATIC AND SEMIAUTOMATIC)

YIELD = 52.5 KSI
ULTIMATE = 95.0 KSI

(C) WELDS (HAND)

YIELD = 58.5 KSI
ULTIMATE = 95.0 KSI

OPERATING, DESIGN AND TEST CONDITIONS

THE OPERATING, DESIGN AND TEST CONDITIONS FOR THE TUNNEL PRESSURE SHELL AND ASSOCIATED SYSTEMS AND ELEMENTS ARE SUMMARIZED BELOW:

1. OPERATING MEDIUM

   ANY MIXTURE OF AIR AND NITROGEN

2. DESIGN TEMPERATURE RANGE

   MINUS 320 DEGREES FAHRENHEIT TO PLUS 150 DEGREES FAHRENHEIT, EXCEPT IN THE REGION OF THE PLENUM BULKHEADS AND GATE VALVES INSIDE A 23-FOOT, 4-INCH DIAMETER, FOR WHICH THE TEMPERATURE RANGE IS MINUS 320 DEGREES FAHRENHEIT TO PLUS 200 DEGREES FAHRENHEIT.

3. PRESSURE RANGE

	TUNNEL CONFIGURATION	OPERATING PRESSURE RANGE, PSIA	DESIGN PRESSURES PSID
A.	CONDITION I - PLENUM ISOLATION GATES OPEN AND TUNNEL OPERATING:		
	TUNNEL CIRCUIT EXCEPT PLENUM	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
	PLENUM (PLENUM PRESSURE IS LIMITED TO .4 TO 1 TIMES THE REMAINDER OF THE TUNNEL CIRCUIT	3.3 to 130	A. 15 EXTERNAL B. 119 INTERNAL
	BULKHEAD		56 (EXTERNAL TO PLENUM)
B.	CONDITION II - PLENUM ISOLATION GATES OPEN AND TUNNEL SHUTDOWN:		
	ENTIRE TUNNEL CIRCUIT	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
	BULKHEAD		0

C. CONDITION III - PLENUM ISOLATION GATES AND ACCESS DOORS CLOSED:

TUNNEL CIRCUIT EXCEPT PLENUM	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
PLENUM (PLENUM OPERATING PRESSURE CAN EXCEED THE PRESSURE IN THE REMAINDER OF THE TUNNEL CIRCUIT BY 24 PSI, BUT DOES NOT EXCEED THE 130 PSIA MAXIMUM OPERATING PRESSURE)	0 to 130	A. 15 EXTERNAL B. 119 INTERNAL
BULKHEAD		A. 25 (INTERNAL TO PLENUM) B. 119 (EXTERNAL TO PLENUM) FOR MINUS 320 DEGREES FAHRENHEIT TO PLUS 150 DEGREES FAHRENHEIT *C. 110.5 (EXTERNAL TO PLENUM) FOR PLUS 151 DEGREES FAHRENHEIT TO PLUS 200 DEGREES FAHRENHEIT

*OPERATING PROCEDURES LIMIT PRESSURES TO THAT SHOWN.

D. CONDITION IV - PLENUM ISOLATION GATES CLOSED AND ACCESS DOORS OPEN:

TUNNEL CIRCUIT EXCEPT PLENUM	8.3 to 130	A. 8 EXTERNAL B. 119 INTERNAL
PLENUM	14.7	0
BULKHEAD		A. 119 (EXTERNAL TO PLENUM) FOR MINUS 320 DEGREES FAHRENHEIT TO PLUS 150 DEGREES FAHRENHEIT *B. 110.5 (EXTERNAL TO PLENUM) FOR PLUS 151 DEGREES FAHRENHEIT TO PLUS 200 DEGREES FAHRENHEIT

*OPERATING PROCEDURES LIMIT PRESSURES TO THAT SHOWN.

4. HYDROSTATIC TEST DESIGN CONDITIONS

THE PRESSURE SHELL WAS DESIGNED FOR HYDROSTATIC TEST IN ACCORDANCE WITH THE REQUIREMENTS OF THE ASME CODE, SECTION VIII, DIVISION 1. THE TEST PRESSURES SHALL BE AS FOLLOWS. PRESSURE SHELL TEMPERATURE SHALL BE EQUAL TO OR BELOW 100°F DURING HYDROSTATIC TESTS.

CONDITION (1) - MAXIMUM INTERNAL PRESSURE CONDITION FOR THE ENTIRE TUNNEL CIRCUIT

$$PH_1 = 1.5\ (119) + \text{HYDROSTATIC HEAD}$$
$$= 178.5\ \text{PSI} + \text{HYDROSTATIC HEAD}$$

CONDITION (2) - MAXIMUM DIFFERENTIAL PRESSURE CONDITION ACROSS THE PLENUM BULKHEADS

$$PH_2 = 1.5\ (119) + \text{HYDROSTATIC HEAD}$$
$$= 178.5 + \text{HYDROSTATIC HEAD}$$

$$PH_2{}^* = 1.5\ (111.5)\ \left(\frac{23.7}{22.2}\right) + \text{HYDROSTATIC HEAD}$$
$$= 178.5 + \text{HYDROSTATIC HEAD}$$

*TUNNEL OPERATION LIMITATIONS PRECLUDE PRESSURE DIFFERENTIALS ACROSS BULKHEADS IN EXCESS OF 110.5 PSI FOR BULKHEAD AND GATE TEMPERATURES IN EXCESS OF 150°F.

CONDITION (3) - MAXIMUM REVERSE DIFFERENTIAL PRESSURE CONDITION ACROSS THE PLENUM BULKHEADS

$$PH_3 = 1.5\ (25) = 37.5\ \text{PSI}$$

THE PRESSURE SHELL EXCEPT FOR THE PLENUM SHALL BE PRESSURIZED TO 141 PSIG. THE PLENUM SHALL BE PRESSURIZED TO 178.5 PSIG.

PRESSURE SHELL STRESS EVALUATION CRITERIA

THIS CRITERIA ESTABLISHES THE BASIS FOR ANALYSIS AND DESIGN OF THE PRESSURE SHELL SO IT WILL MEET OR EXCEED ALL OF THE REQUIREMENTS OF SECTION VIII, DIVISION 1 OF THE ASME BOILER AND PRESSURE VESSEL CODE AND CAN BE STAMPED WITH A DIVISION 1 "U" STAMP.

1. SECTION VIII, DIVISION 1, DIRECT APPLICATION

A. THE MAXIMUM ALLOWABLE STRESS (S)

$S = 23.7$ KSI (-320°F TO +150°F)

$S = 22.2$ KSI (-320°F TO +200°F)

(B) PRIMARY BENDING PLUS PRIMA~~RY~~ MEMBRANE STRESSES

THE LOCAL MEMBRANE STRESSES ARE NOT GENERALLY CONSIDERED IN SECTION VIII, DIVISION 1 DESIGNS. HOWEVER, FOR THE PURPOSE OF DESIGNING LOCAL REINFORCEMENT AT BRACKETS, RINGS OR PENETRATIONS NOT COVERED BY DESIGN BASED ON STRESS ANALYSIS, THE LOCAL SHELL MEMBRANE STRESS SHALL BE:

$$P_b + P_m \leq 1.5\ SE$$

NOTE: E IS JOINT EFFICIENCY

2. IN REGIONS OF THE PRESSURE SHELL WHERE DIVISION 1 DOES NOT CONTAIN RULES TO COVER ALL DETAILS OF DESIGN (REF. U-2(g)), ADDITIONAL ANALYSES WERE PERFORMED UTILIZING THE GUIDELINES OF THE ASME CODE, SECTION VIII, DIVISION 2, APPENDIX 4, "DESIGN BASED ON STRESS ANALYSIS." THE BASIC STRESS CRITERIA FOR DIVISION 2 IS REPRESENTED IN FIGURE 4-130.1 AND RESTATED BELOW INDICATING ANY MODIFICATIONS OR EXCESS REQUIREMENTS APPLIED TO IT TO REMAIN WITHIN THE INTENT OF DIVISION 1 AND TO OBTAIN A DIVISION 1 STAMP.

A. GENERAL PRINCIPAL MEMBRANE STRESS

MAXIMUM ALLOWABLE STRESS

$S = 23.7$ KSI (-320°F TO +150°F)

$S = 22.2$ KSI (-320°F TO +200°F)

MAXIMUM ALLOWABLE STRESS INTENSITY

$S_m = 31.7$ KSI (-320°F TO +200°F)

B. PRIMARY GENERAL MEMBRANE STRESS INTENSITY

$$P_m \leq S_m$$

AND IN ORDER TO COMPLY WITH DIVISION 1, THE MAXIMUM PRINCIPAL MEMBRANE STRESS MUST BE:

$$P_m^* \leq S$$

NOTE: THE * IS USED TO DENOTE THAT MAXIMUM PRINCIPAL STRESSES ARE TO BE COMPUTED FOR THE GIVEN LOADING CONDITION. THE INTENT IS TO DETERMINE THE STRESSES WHICH REPRESENT THE HOOP STRESSES AND MERIDIONAL STRESSES WHICH ARE THE STRESSES USED IN DIVISION 1 COMPUTATIONS.

...

C. DESIGN LOADS, PRIMARY LOCAL MEMBRANE STRESS INTENSITY

$$P_L \leq 1.5\ S_m$$

NOTE: LOCAL MEMBRANE STRESS INTENSITY IS DEFINED IN ACCORDANCE WITH DIVISION 2, APPENDIX 4-112(i). THE TOTAL MERIDIONAL LENGTH IS CONSIDERED TO BE 1.0 $\sqrt{RT}$!

D. DESIGN LOADS, PRIMARY LOCAL MEMBRANE PLUS PRIMARY BENDING STRESS INTENSITY

$$P_L + P_b \leq 1.5\ S_m$$

E. OPERATING LOADS, PRIMARY PLUS SECONDARY STRESS INTENSITY

$$P_L + P_b + Q \leq 3\ S_m$$

F. COMMENT

BECAUSE OF THE LOW YIELD STRENGTH EXPECTED AT THE WELDS AS COMPARED TO THE YIELD STRENGTH OF THE PLATE, STRESS INTENSITIES COMPUTED IN (A), (B), (C), (D), OR (E) SHALL NOT EXCEED THE YIELD STRENGTH OF THE MATERIAL AT EITHER WELD OR PLATE LOCATIONS.

3. A FATIGUE ANALYSIS WAS CONDUCTED IN ACCORDANCE WITH SECTION VIII, DIVISION 2 WITHOUT MODIFICATION.

4. HYDROSTATIC TEST CONDITION DESIGN CONSIDERATIONS

A. PRESSURE SHELL

IN ACCORDANCE WITH DIVISION 1 OF THE ASME CODE, DESIGN ANALYSIS OF THE PRESSURE SHELL FOR THE HYDROSTATIC TEST CONDITION IS NOT REQUIRED. HOWEVER, IN ORDER TO PROVIDE A SATISFACTORY ENGINEERING DESIGN FOR THE PRESSURE SHELL THE FOLLOWING CRITERIA WAS USED:

(a) THE MAXIMUM GENERAL MEMBRANE STRESS PERPENDICULAR TO A WELD LINE WAS LIMITED TO THE LESSER OF:

$$P_m{}^* \leq 0.8 \text{ WELD YIELD STRESS}$$

OR

$$P_m{}^* \leq 0.5 \text{ WELD ULTIMATE STRESS}$$

(b) THE GENERAL PRINCIPAL MEMBRANE STRESS IN THE PLATE (NOT AT A WELD) WAS LIMITED TO THE LESSER OF:

P_m * $\leq$ 0.8 PLATE YIELD STRESS

P_m * $\leq$ 0.5 PLATE ULTIMATE STRESS

(*) THE STRESSES SATISFYING THIS CRITERIA ARE BASED ON MAXIMUM MEMBRANE STRESSES RATHER THAN INTENSITY CRITERIA.

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Vol. 3

Finite Element Analyses of Plenum Region Including the Side Access Reinforcement, Side Access Door and Angle of Attack Penetration

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Part 1 Plenum

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Part 2 Door

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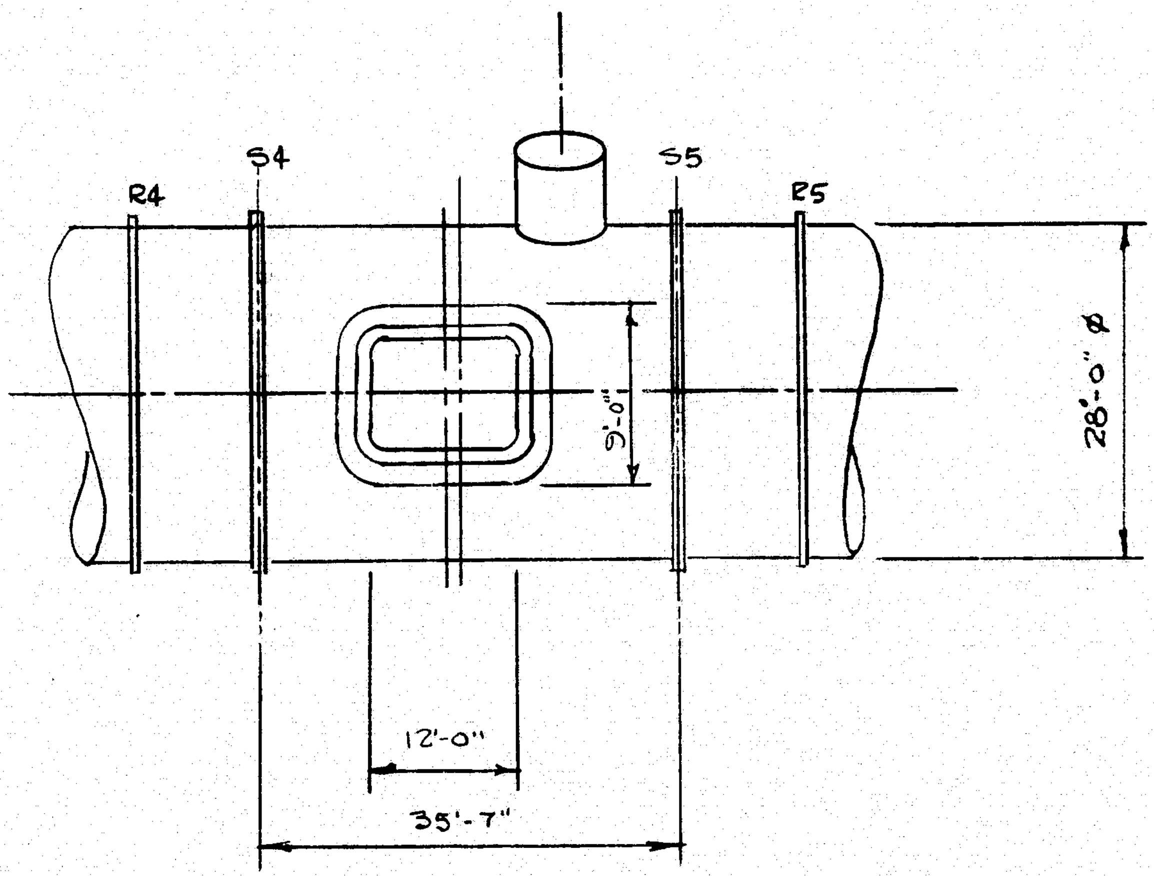
OF ACCESS DOOR REINFORCEMENT

(Plenum)

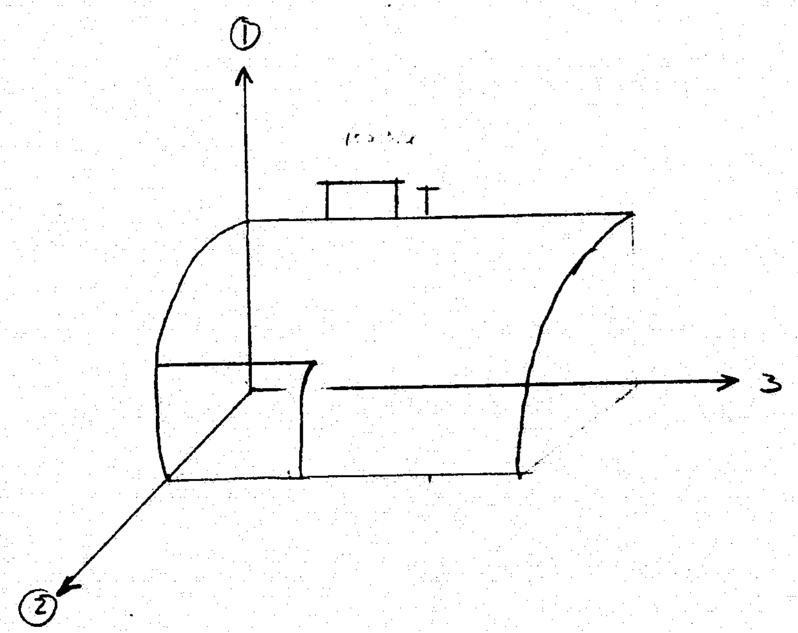
9% Ni

REFERENCE DRAWING NO. LE-944431



SPAR (a finite element computer code developed & maintained by Engineering Information System, Inc. under NASA contract NAS8-30536 and NAS1-13977) was used to analyze this region of the pressure shell. The region was modeled using, triangular and quadrilateral, membrane plus bending flat aeolotropic elements. The "T" ring and flange was modeled with general beam elements.

A 90° segment of the pressure shell (Plenum) was modeled from the ℄ of the access opening to beyond the support ring S5. A plane thru the access opening perpendicular to the axis of the shell is a plane of symmetry. Horizontal & vertical planes thru the axis of the shell are also planes of symmetry.



Plane of symmetry 1-2 plane
1-3 plane
2 3 plane

A computer plot of the model is shown in fig 1. The model consists of 1092 joints with 6 DOF per joint except where boundary conditions were applied and rotation about an axis ⊥ to a plate element was restricted.

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The joint numbers for the model are shown in Fig 2 thru Fig. 10

The shell section properties (plate thickness) are shown in Fig 11 thru Fig. 19

Shell Section Property	Thickness
1	1.75
2	2.00
3	1.00
4	4.50
5	2.00
6	3.00
7	1.75
8	3.25
9	1.00
10	2.75
11	2.375

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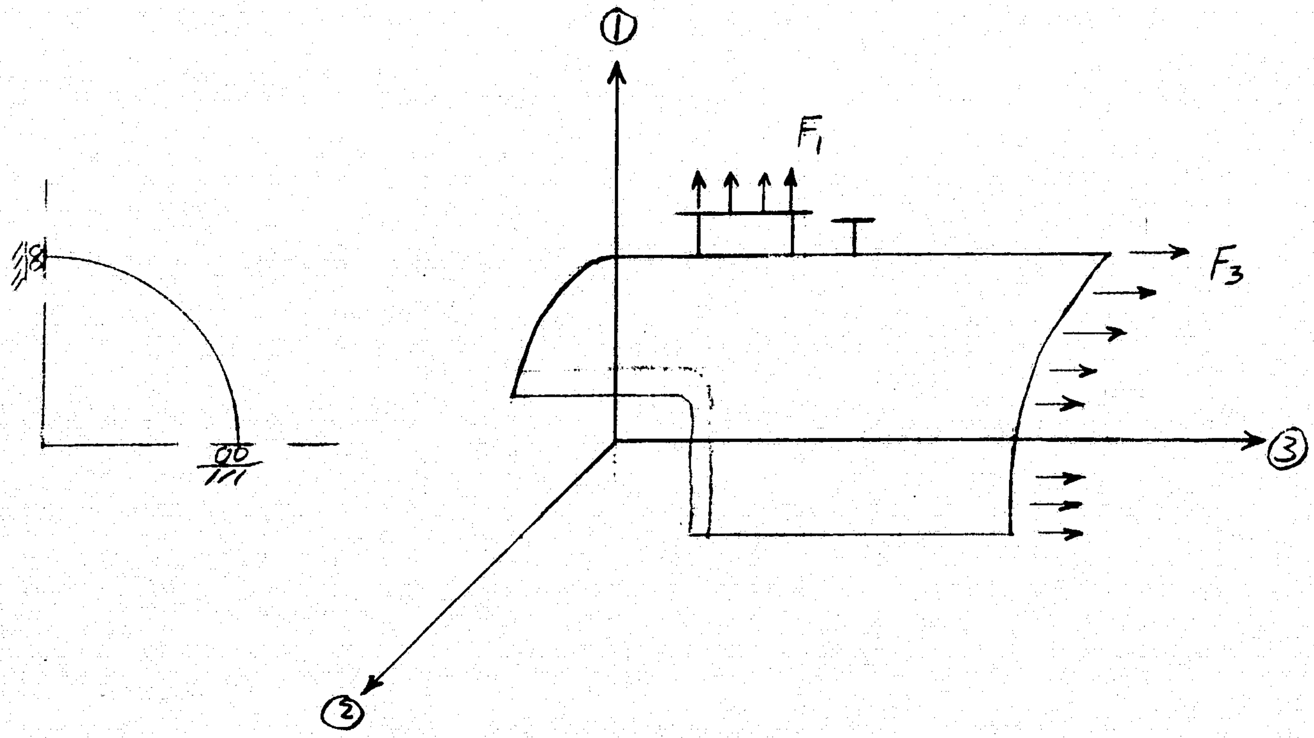
Boundary Conditions



1 2 plane is a plane of symmetry
1 3 plane is a plane of symmetry
2 3 plane is a plane of symmetry

on boundary of cylinder and pipe - restrict rotation about θ & z axes (cy. cord.)

Boundary Forces

Cylinder

$F = (\pi R^2)(P) = \pi(169^2)(119) = 10{,}677{,}516$ lbs.

For $\frac{1}{4}$ model

$F_3 = \frac{F}{4} = \frac{10{,}677{,}516 \text{ lbs.}}{4}$

$F_3 = 2{,}669{,}379$ lbs.

This force was applied uniformly around 1/4 cylinder model

on Joint 1 + 16 — 88,979.2 lbs.
2 thru 15 — 177,958.3 lbs.

Pipe

$F = (\pi R^2)(P) = \pi(50^2)\,119 = 934{,}623.8$ lbs.

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For a $\frac{1}{2}$ model of pipe

$$F_1 = \frac{F}{2} = \frac{934623.8}{2} \text{ lbs}$$

$$F_1 = 467{,}311.9 \text{ lbs.}$$

This force was applied uniformly around a ½ pipe model

Joint 1056 + 1092 – 6490 lb
1057 thru 1091 – 12980 lbs

9' X 12' opening

Forced displacements obtained from combining the Door and Plenum models were applied to the 9' X 12' opening. See discussion on combined analyses. (p. 9)

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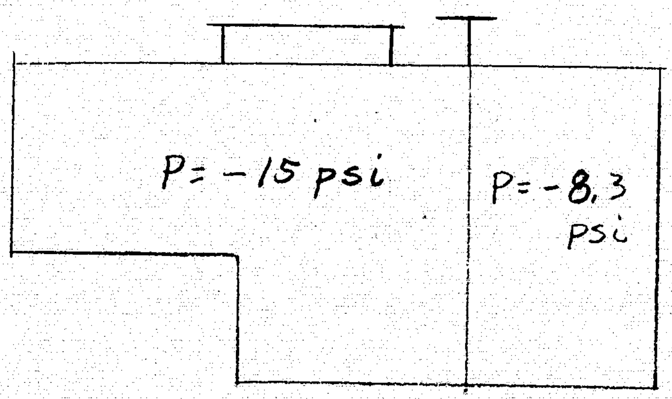
Loading

Internal Pressure

P= 119 psi (design pressure) was applied as nodal pressure to the joints of the pressure surface.

External Pressure

Nodal pressure was applied to the joints of the pressure surface according to the following sketch.



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Combined Door + Plenum Analyses

see Finite Element Analyses of Side Access Door

To determine the interaction of the door and plenum, a combined reduced stiffness matrix from the 2 models (Plenum and Door) was generated. From this the relative displacement between the door and plenum (sealing surfaces) was determined for internal pressure. Nodal displacements from the combined run were used as boundary conditions at the sealing surfaces of the Door and Plenum to compute the final stress in each model.

For vacuum condition, the dog loads and relative displacement between the door + plenum (sealing surfaces) was determined.

Results

Nodal stresses are presented in Fig 20 thru Fig 67
The max principal stress (PS1) or min principal stress (PS2) are given for the mid-surface (surface 0), the inside surface (surface 1), and outside surface (surface 2).

The stresses plotted are for joint 1 of the element. As an example (reference Fig 2), for the element defined by joints 17, 18, 34, 33 joint 1 for that element is 17.

Nodal stresses for one joint are given from 4 elements (for quadrilateral elements). If any discrepancies exist in the stresses for a joint, the largest value is used in the interpretation of the results.

The displacement of the sealing surfaces for the Door and plenum for an internal P = 119 psi is given in table 1.

The sealing surfaces of the Door and Plenum remained in contact. (the relative displacements of the sealing surfaces was minus)

TABLE 1

P = 119 psi

* CONNECT POINT NO.	DISPLACEMENTS AT SEALING SURFACE		RELATIVE DISPLACEMENT
	PLENUM	DOOR	
1	.0936	.0947	-.00110
2	.0845	.0854	-.00090
3	.0650	.0658	-.00083
4	.0398	.0400	-.00013
5	.0209	.0210	-.00009
6	.0110	.0114	-.00042
7	.0109	.0113	-.00032
8	.0109	.0115	-.00053
9	.0099	.0103	-.00034
10	.0098	.0099	-.00013

* SEE FIGURE 68

ALL RELATIVE DISPLACEMENTS ARE NEGATIVE
∴ ALL POINTS ALONG SEALING SURFACES OF DOOR AND PLENUM REMAIN IN CONTACT.

RELATIVE DISPLACEMENTS X STIFFNESS (1.0×10^8) RESULTS IN A TOTAL DOOR FORCE OF 480,544 lb.

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The displacement and relative displacement of the sealing surfaces of the Door and Plenum for vacuum conditions (external pressure = 15 psi) are given in table 2.

The dog loads for vacuum conditions are also given in Table 2.

TABLE 2

VACUUM PRESSURE

* CONNECT POINT NO.	DISPLACEMENTS AT SEALING SURFACE		RELATIVE DISPLACEMENT
	PLENUM	DOOR	
1	−.00661	−.02421	.01760
2	−.00555	−.02168	.01614
3	−.00318	−.01687	.01370
4	−.00035	−.00991	.00956
5	.00303	−.01389	.01691
6	.00501	−.01980	.02481
7	.00502	−.02351	.02853
8	.00503	−.02638	.03141
9	.00543	−.02806	.03349
10	.00547	−.02862	.03409

* SEE FIGURE 68
CONNECT POINTS 1−4 ARE DOG LOCATIONS AND ARE THE ONLY POINTS CONSIDERED TO BE TIED TOGETHER DURING VACUUM P.[illegible]

FORCES AT DOGS −

	REL. DISP.	X DOG STIFFNESS	= FORCE
*1	.01760	.63 E+6	11088. #
2	.01614	.63 E+6	10167.
3	.01370	.63 E+6	8628.
4	.00956	3.21 E+6	30689.
			Total 60572. #

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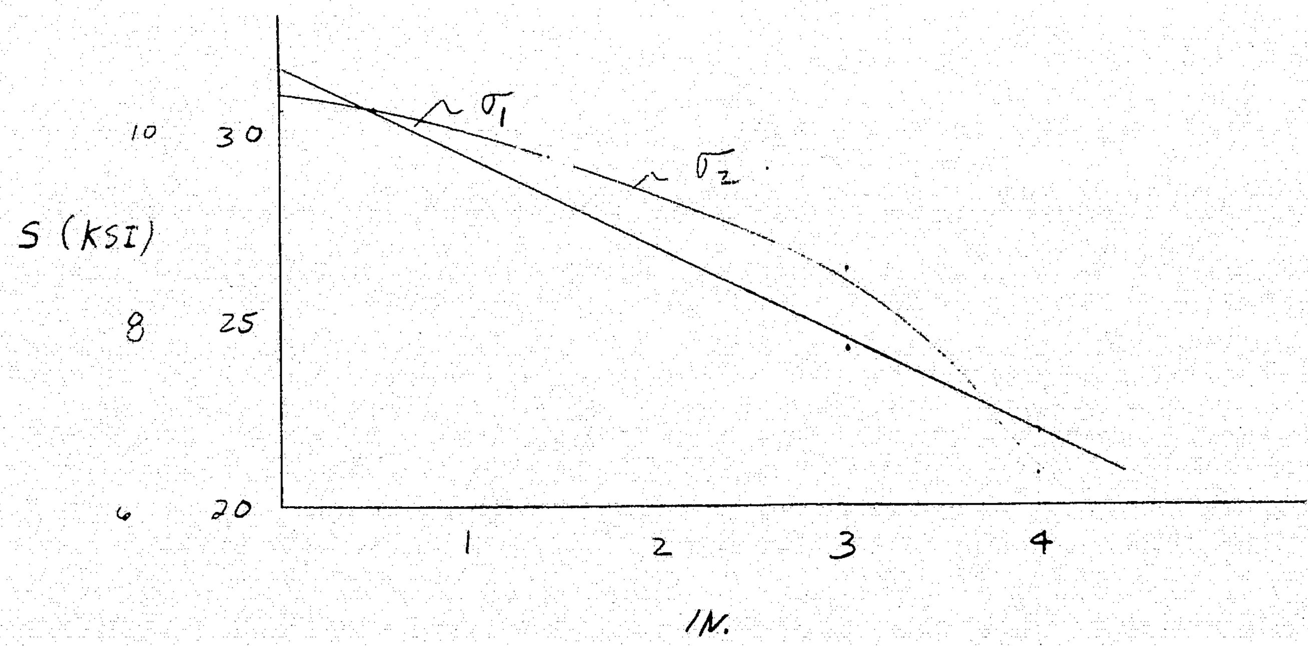
Region around the 9'x12' Opening

Max Membrane stress occurs in the corners.
See Fig 44

The max stress is at
group 4 ind. 16

Since stress at surface 0 is at centroid of element, the stress is projected to edge of plate



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$\sigma_1 = 31.6$ KSI

$\sigma_2 = 10.40$ KSI

$\sigma_3 = -\frac{.119}{2} = -.06$ KSI

$S_{12} = 31.16 - 10.40 = 20.76$ KSI

$S_{23} = 10.40 - (-.06) = 10.46$ KSI

$S_{31} = -0.06 - 31.6 = -31.66$ KSI

$P_L = |-31.66| = 31.66$ KSI

$P_L \leq 1.5\ S_m$

$31.66 < 1.5\ (31.7) = 47.55$ KSI

O.K.

The meridional distance at a stress intensity of $1.1\ S_m$ (34.87 KSI) is 0

$0 < \sqrt{RT}$

∴ The region meets the criteria for Primary local membrane stress intensity.

General Membrane Stress Intensity

2/2/137 (away from opening)

See fig 20

$\sigma_1 = 11.89$ KSI

$\sigma_2 = 5.58$ KSI

$\sigma_3 = -\frac{.119}{2} = -.06$ KSI

$S_{12} = 11.89 - 5.58 = 6.31$ KSI

$S_{23} = 5.58 - (-.06) = 5.64$ KSI

$S_{31} = -.06 - 11.89 = -11.95$ KSI

$P_m = |-11.95| = 11.95$ KSI

$P_m \leq S_m$

$11.95 \leq 31.7$ KSI O.K.

General Principal Membrane Stress

$\sigma_1 = 11.89$ KSI

$\sigma_1 \leq S$

$11.89 < 23.7$ KSI O.K.

∴ The general principal membrane stress and general membrane stress intensity for the Plenum region meets the stress evaluation criteria.

Primary Plus Secondary Stress Intensity

Inside Surface (see Fig 46)

Max stress intensity at

4 / 17 / 518

To correct for stress at edge

add 31.6 - 30.48 = 1.12 to σ_1

add 10.4 - 10.25 = .15 to σ_2

$\sigma_1 = 46.27 + 1.12 = 47.39$ KSI

$\sigma_2 = 23.25 + .15 = 23.40$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = 47.39 - 23.40 = 23.99$ KSI

$S_{23} = 23.40 - (-.12) = 23.52$ KSI

$S_{31} = -.12 - 47.39 = -47.51$ KSI

$P_L + P_b + Q = |-47.51| = 47.51$ KSI

BY __________ DATE ________ SUBJECT ______________________ SHEET NO. 20 OF ______

CHKD. BY ______ DATE ________ JOB NO. ______________

$P_L + P_b + Q < \sigma_{yp}$

$47.51 < 52.5$ KSI (auto weld)

O.K.

Outside Surface (see Fig 45

Max at 4/16/518

apply same correction as above

$\sigma_1 = 25.77 + 1.12 = 26.89$ KSI

$\sigma_2 = -2.07 + .15 = -1.92$ KSI

$\sigma_3 = 0$

$S_{12} = 26.89 - (-1.92) = 28.81$ KSI

$S_{23} = -1.92 - 0 = -1.92$ KSI

$S_{31} = 0 - 26.89 = 26.89$ KSI

$P_L + P_b + Q = |28.81| = 28.81$ KSI

BY ________ DATE ________ SUBJECT ________ SHEET NO. 21 OF ____

CHKD. BY ________ DATE ________ JOB NO. ________

$$P_L + P_b + Q < \sigma_{YP}$$

$$28.81 < 52.5 \text{ KSI} \quad (\text{auto weld})$$

O.K.

The primary plus secondary stress intensity for the region around the 9' X 12' opening meets the stress evaluation criteria.

BY ______ DATE ______ SUBJECT ______ SHEET NO. 22 OF ______
CHKD. BY ______ DATE ______ JOB NO. ______

Inside Stiffner Ring

See Fig 38

At 6/36/591

Membrane Stress

$\sigma_1 = 27.03$ KSI

$\sigma_2 = -5.98$ KSI

$\sigma_3 = 0$

$S_{12} = 27.03 - (-5.98) = 33.01$ KSI

$S_{23} = -5.98 - 0 = -5.98$ KSI

$S_{31} = 0 - 27.03 = -27.03$ KSI

$P_L = |33.01| = 33.01$ KSI

$P_L \leq 1.5\ S_m$

$$33.01 < 1.5(31.7) = 47.55 \text{ KSI}$$

This stress is a local stress at a nozzle.

∴ This region meets the criteria for local membrane stress intensity

Primary plus secondary Stress Intensity

The max stress intensity is on the pressure side of the stiffner. (6/43/682) (Fig 39)

$\sigma_1 = 29.64$ KSI
$\sigma_2 = -21.19$ KSI
$\sigma_3 = -.119$ KSI

$S_{12} = 29.64 - (-21.19) = 50.83$ KSI
$S_{23} = -21.19 - (-.119) = -21.31$ KSI
$S_{31} = -.12 - 29.64 = 29.52$ KSI

$P_L + P_b + Q = |50.83| = 50.83$ KSI

$P_L + P_b + Q < \sigma_{yp}$

$50.83 < 52.5$ KSI (auto weld)

O.K

BY ____________ DATE ________ SUBJECT ______________________________ SHEET NO. 15 OF ______

CHKD. BY ______ DATE ________ JOB NO. ________________

$\therefore$ This region meets the criteria for primary + secondary stress intensity

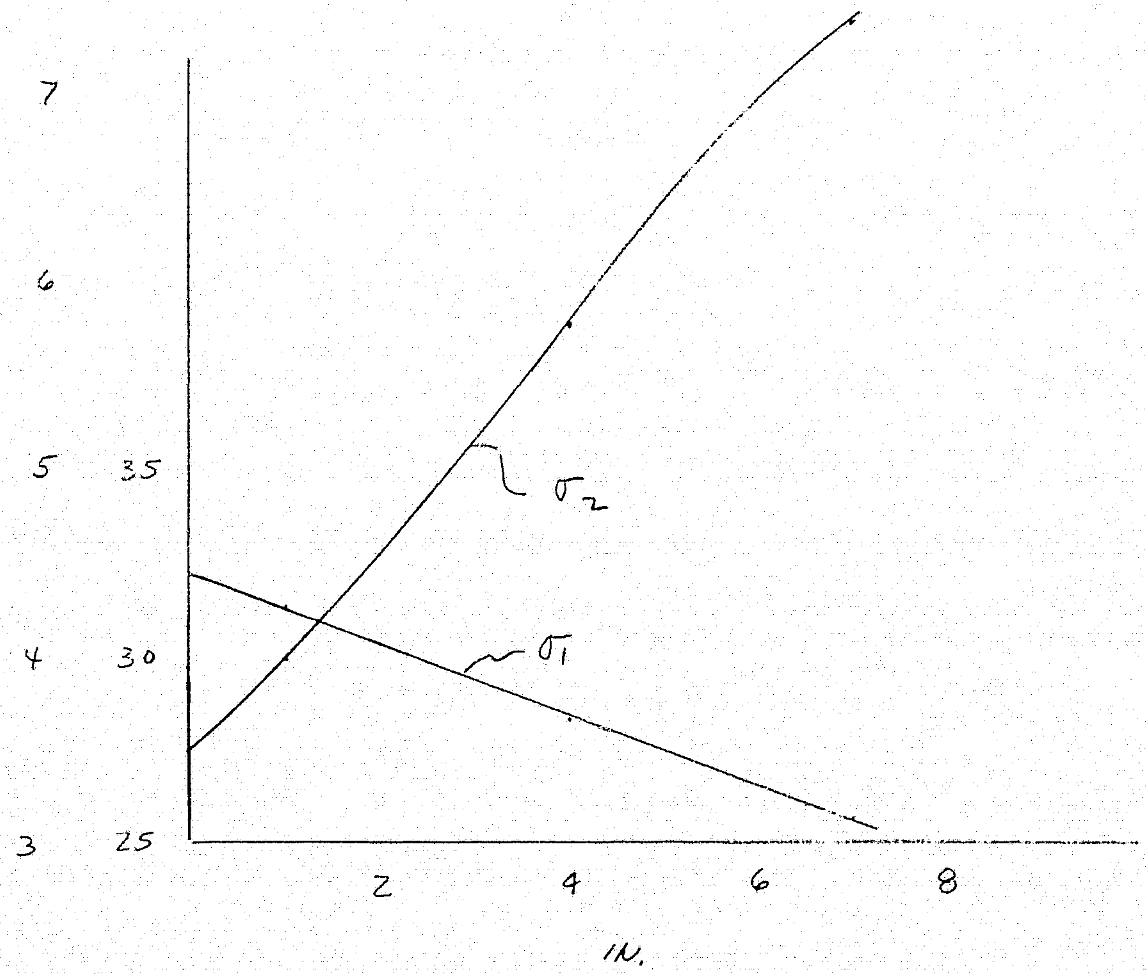
BY ______ DATE ______ SUBJECT ______ SHEET NO. 26 OF ______
CHKD. BY ______ DATE ______ JOB NO. ______

Region Around 8.33' dia circular hole

Ref. fig. 50

Max membrane stress at 6/71

Since stress at surface 0 is for centroid of element, the stress is projected to edge of plate.



BY ______ DATE ______ SUBJECT ______ SHEET NO. 22 OF ______
CHKD. BY ______ DATE ______ JOB NO. ______

$$\sigma_1 = 32.2 \text{ KSI}$$

$$\sigma_2 = 3.5 \text{ KSI}$$

$$\sigma_3 = -\frac{.119}{2} = -.06 \text{ KSI}$$

$$S_{12} = 32.2 - 3.5 = 28.7 \text{ KSI}$$

$$S_{23} = 3.5 - (-.06) = 3.56 \text{ KSI}$$

$$S_{31} = -.06 - (32.2) = -32.26 \text{ KSI}$$

$$P_L = |-32.26| = 32.26 \text{ KSI}$$

$$P_L \leq 1.5 \, Sm$$

$$32.26 < 1.5(31.7) = 47.55 \text{ KSI}$$

This stress is a local stress at nozzle

∴ This region meets the criteria for local membrane stress intensity

Primary Plus Secondary Stress intensity

Outside Surface (Fig 50)

Max stress at 6/1/1760

To correct for stresses at edge of plate

add 32.2 − 31.2 = 1.0 KSI σ_1

add 3.5 − 3.97 = −.47 KSI σ_2

$\sigma_1 = 34.39 + 1.0 = 35.39$ KSI

$\sigma_2 = 22.44 + (-.47) = 21.97$ KSI

$\sigma_3 = 0$

$S_{12} = 35.39 - 21.97 = 13.42$ KSI

$S_{23} = 21.97 - 0 = 21.97$ KSI

$S_{31} = 0 - 35.39 = -35.39$ KSI

BY ____ DATE ____ SUBJECT ____ SHEET NO. 29 OF ____
CHKD. BY ____ DATE ____ JOB NO. ____

$$P_L + P_b + Q = |-35.39| = 35.39 \text{ KSI}$$

$$P_L + P_b + Q < \sigma_{YP}$$

$$35.39 < 52.5 \text{ KSI} \quad \text{(auto welds)}$$

O.K.

Inside Surface 6/71 / 796
(see Fig 54)

$$\sigma_1 = 27.41 + 1.0 = 28.41 \text{ KSI}$$

$$\sigma_2 = -18.25 + (-.47) = -18.72 \text{ KSI}$$

$$\sigma_3 = -\frac{.119}{2} = -.06 \text{ KSI}$$

$$S_{12} = 28.41 - (-18.72) = 47.13 \text{ KSI}$$

$$S_{23} = -18.72 - (-.06) = -18.66 \text{ KSI}$$

$$S_{31} = -.06 - 28.41 = 28.47 \text{ KSI}$$

$$P_L + P_b + Q = |47.13| = 47.13 \text{ KSI}$$

$$P_L + P_b + Q < \sigma_{YP}$$

$$47.13 < 52.5\ KSI$$ (auto welds)

O.K.

The primary plus secondary stress intensity for this region meets the stress evaluation criteria.

The holes used in this analyses is 8.33' dia. The thickness of reinforcement is 2.75 IN. The hole shown on drawing LE 944429 is 6.0' dia. The thickness of reinforcement is 4¼".

Sine the larger dia & smaller reinforcing thickness meets the stress evaluation criteria, the 6.0 dia hole was not analyses. It was assumed to also meet the criteria.

Hydro Test Conditions

Local membrane stress exists around the 9' X 12' opening and the 8.33' dia circular opening. The max general membrane stress outside these region and between S4 and S5 is

$$\sigma_X = 11.89 \text{ KSI} \qquad (P = 119 \text{ psi})$$

For the plenum region, the pressure at hydro is

$$P_H = 1.5(119) + 62.4 \frac{lb}{ft^3} \frac{1}{144} \frac{ft^2}{in^2} \left[\frac{41}{2} + \frac{28}{2} \right] ft$$

$$P_H = 178.5 + 14.95$$

$$P_H = 193.45 \text{ psi}$$

∴ The general membrane stress at hydro is

$$\sigma_{X_H} = \frac{193.45}{119} (11.89)$$

$$\sigma_{X_H} = 19.33 \text{ KSI}$$

The stress at hydro limited to

.8 (52.5) = 42 KSI for auto welds

19.33 < 42.0 KSI O.K.

∴ The plenum meets the criteria for hydro test conditions

Buckling of Plenum

The critical load factor for the plenum region at a pressure of − 15 psi is 12.0. Buckling occured at the center plenum

A modal plot is shown in fig. 69

BY ____ DATE ____ SUBJECT ____ SHEET NO. 34 OF ____
CHKD. BY ____ DATE ____ JOB NO. ____

Model check points

axial + hoop stress in 1" section of shell

$$S_H = \frac{Pr}{t} = \frac{(119)(169)}{1.0} = 20.1\ KSI$$

$$S_a = \frac{Pr}{2t} = \frac{(119)(169)}{2(1)} = 10.0\ KSI$$

Stress at surface O

$S_1 = 19.95$ KSI

$S_2 = 10.05$ KSI

∴ stresses on 1" section of cylinder check with hand calculation

Model check - Buckling

Ref. Theory of Elastic Stability
Timoshenko & Gere
Second Edition
p. 495 to 497

Buckling under Combined Axial and Uniform Lateral Pressure

Assume shell to be simply supported. and a uniform cylinder with
$t = 1.75$ $R = 168.875''$ $L = 427''$
$E = 29 \times 10^6$ psi $\mu = 0.3$

The critical pressure is 122.5 psi

The critical load factor for 15 psi is 8.2

Ref: Stress in Shell
W. Flügge
Second Printing
p. 432 to 434

BY__________ DATE__________ SUBJECT__________ SHEET NO. 36 OF______
CHKD. BY______ DATE__________ JOB NO.__________

For External Pressure only

Assume edges clamped and a uniform cylinder with $t = 1.75$

$R = 168.75$ $L = 427''$ $E = 29 \times 10^6$ psi

$\mu = 0.3$

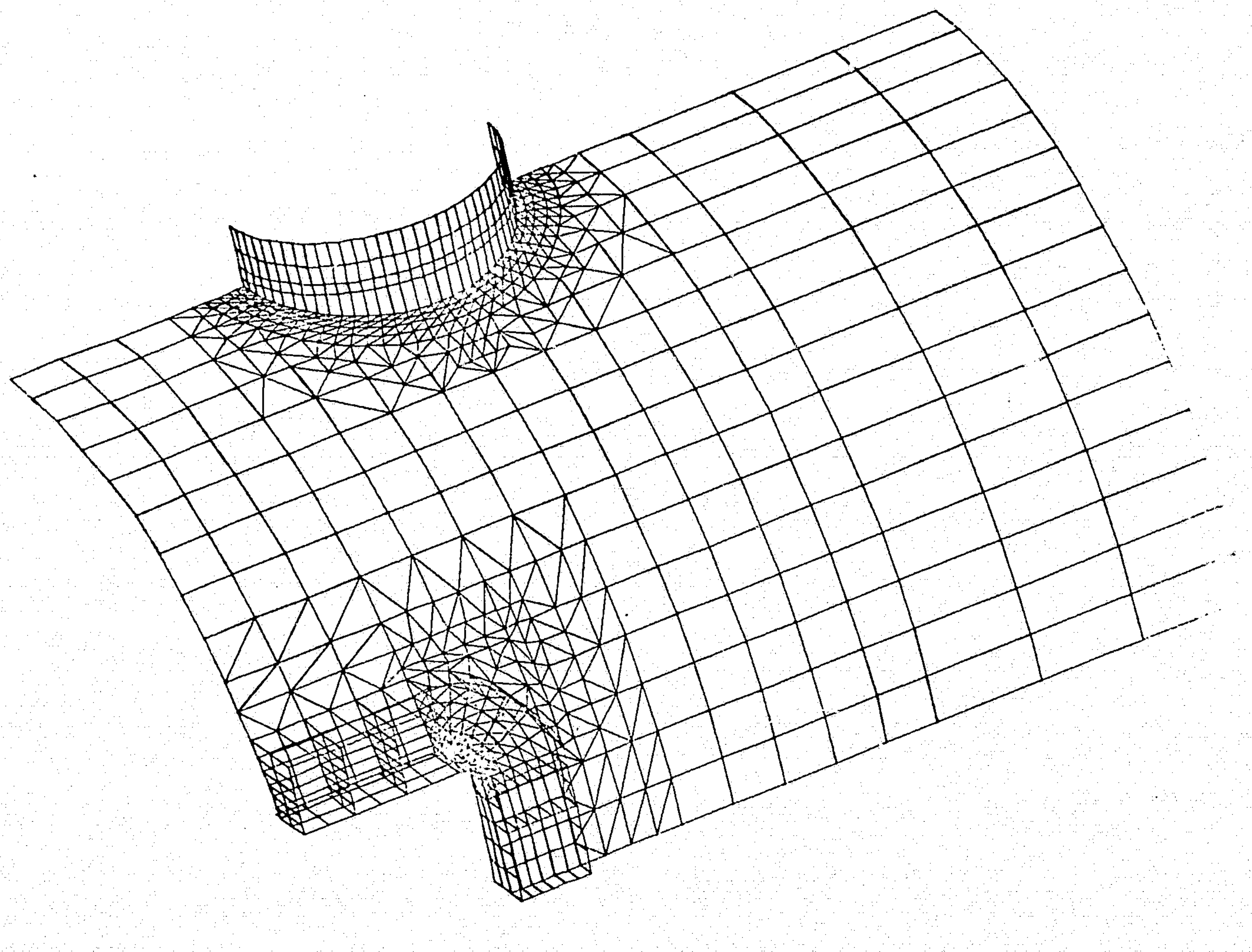
The critical pressure is 123.9 psi

The critical load factor for 15 psi is 8.3

Timoshenk & Flügge yield critical load factor lower than the finite element solution (8.3 vs 12.6)

This can be explain by the fact part of the shell in the finite element solution is 2" thick and the heavy reinforcing provided around the openings.

∴ Model is O.K.

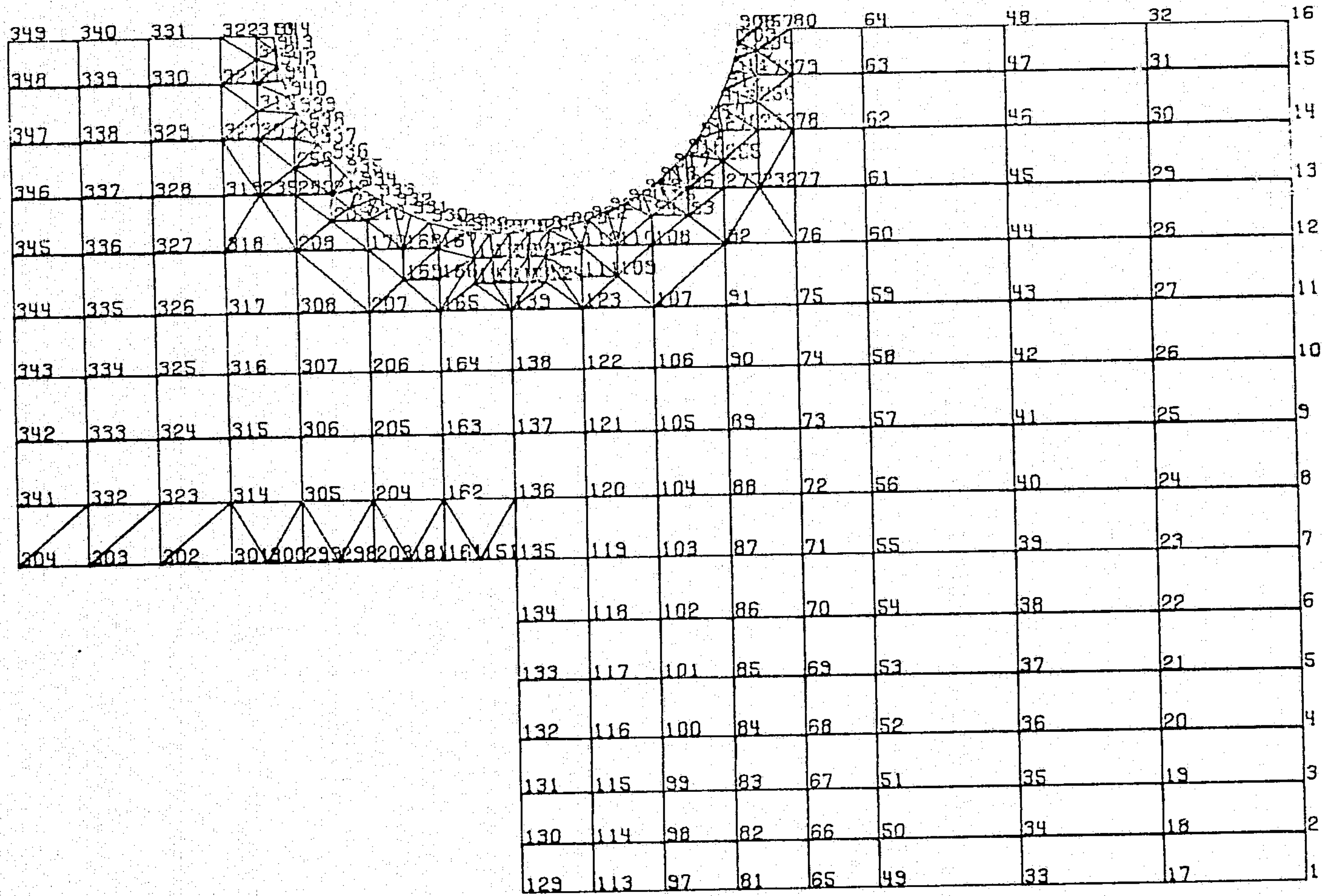


SPEC 1.1

NTF 9 X 12 ACCESS OPENING

0 ______ 64
SCALE

FIGURE 1

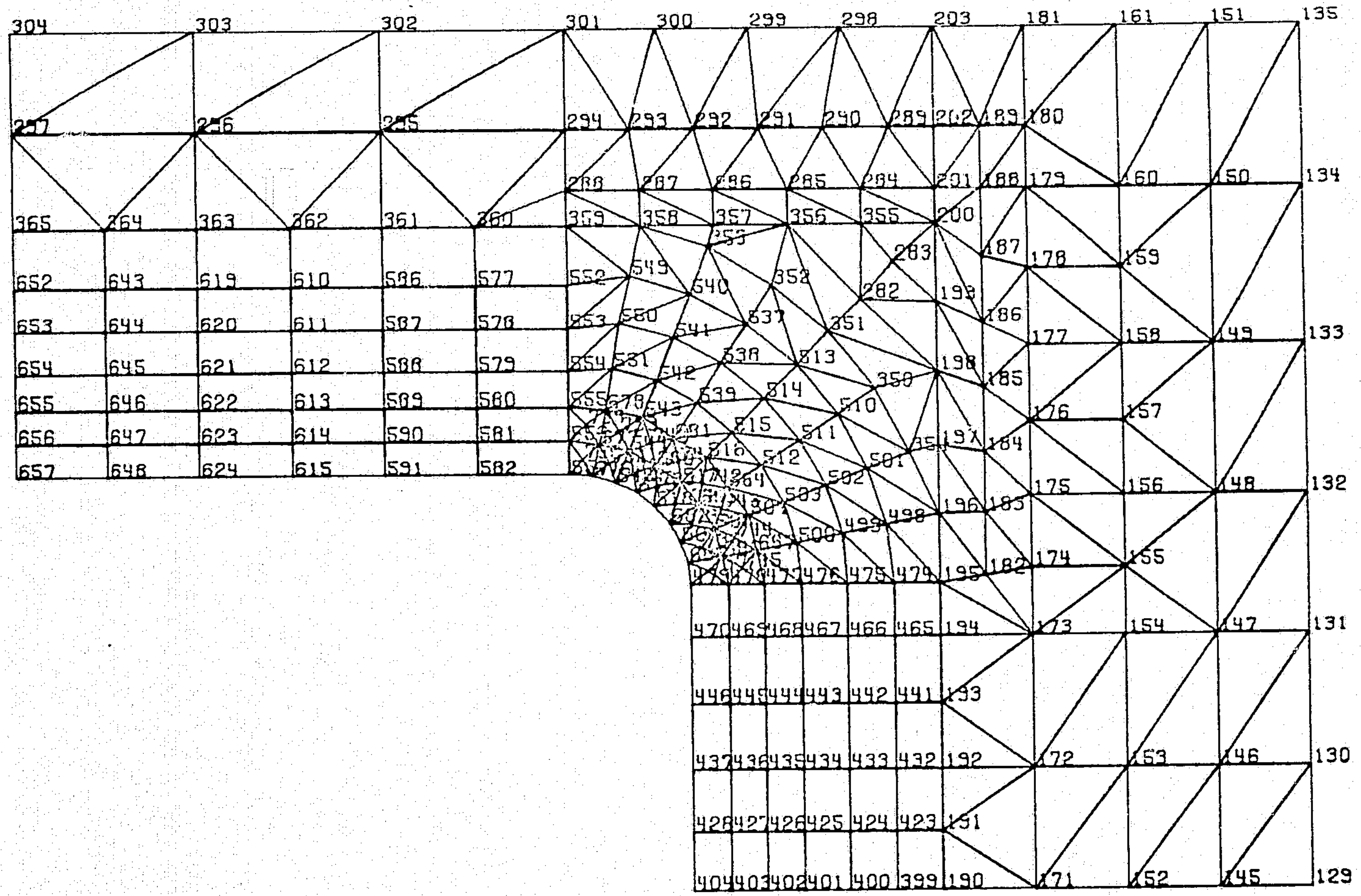


SPEC 3.1

NTF 9 X 12 ACCESS OPENING SHELL

0 55 SCALE

Figure 2



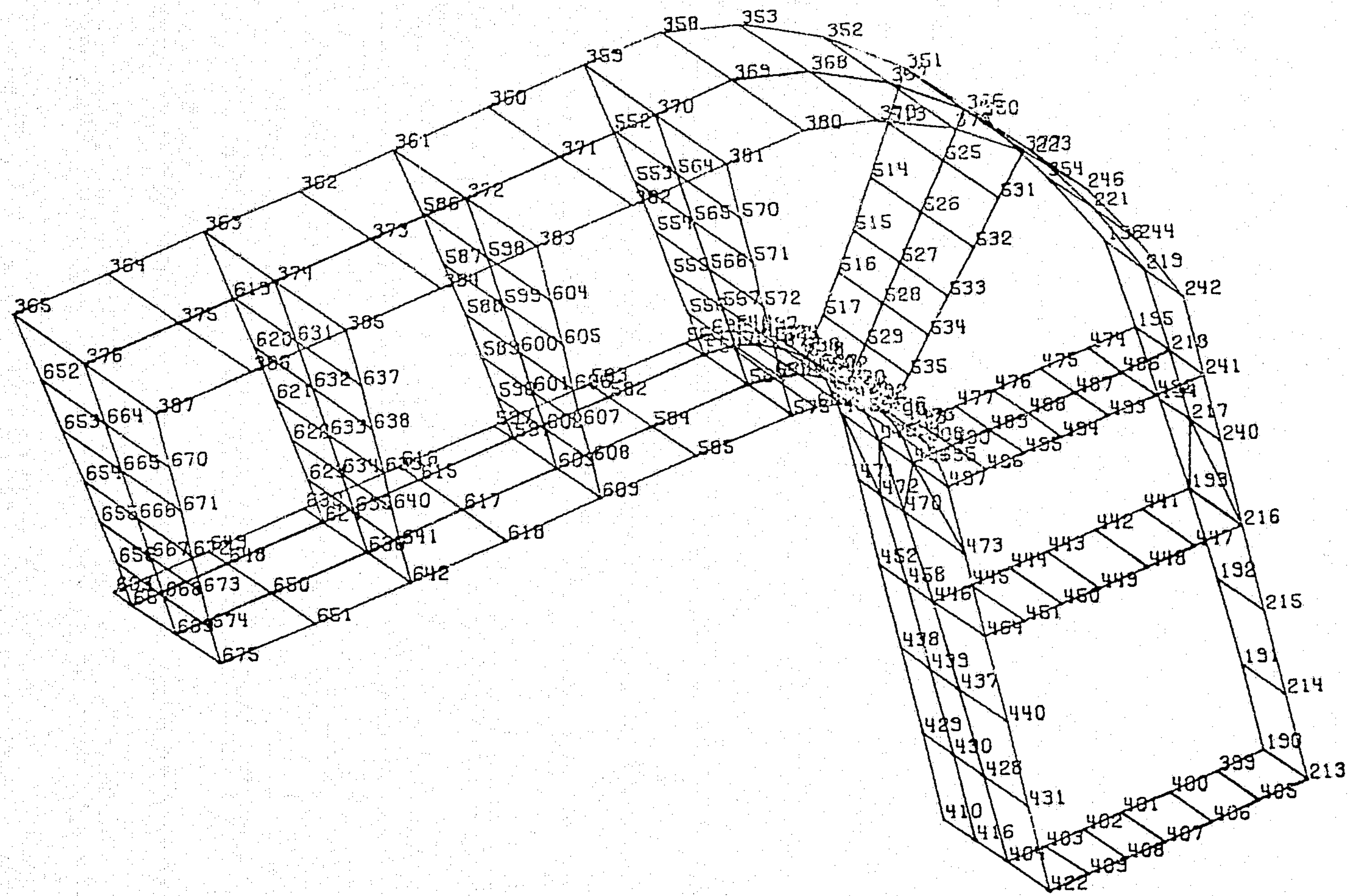
SPEC 4.1

NTF 9 X 12 ACCESS OPENING SHELL

0 21 SCALE

Figure 3

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

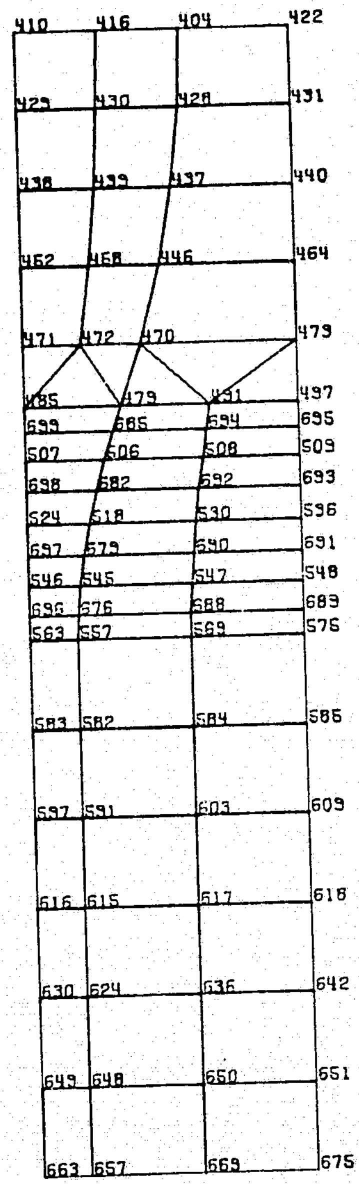


0 18
SCALE

SPEC
5.1

NTF 9X12 ACESS OPENING
GUSSET

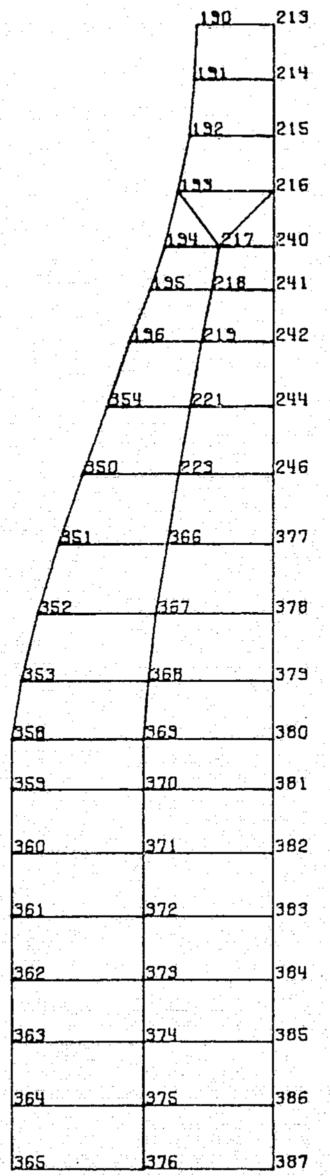
Figure 4



0 14
SCALE

SPEC 6.1 NTF 9X12 REINF.
INNER RING

Figure 5

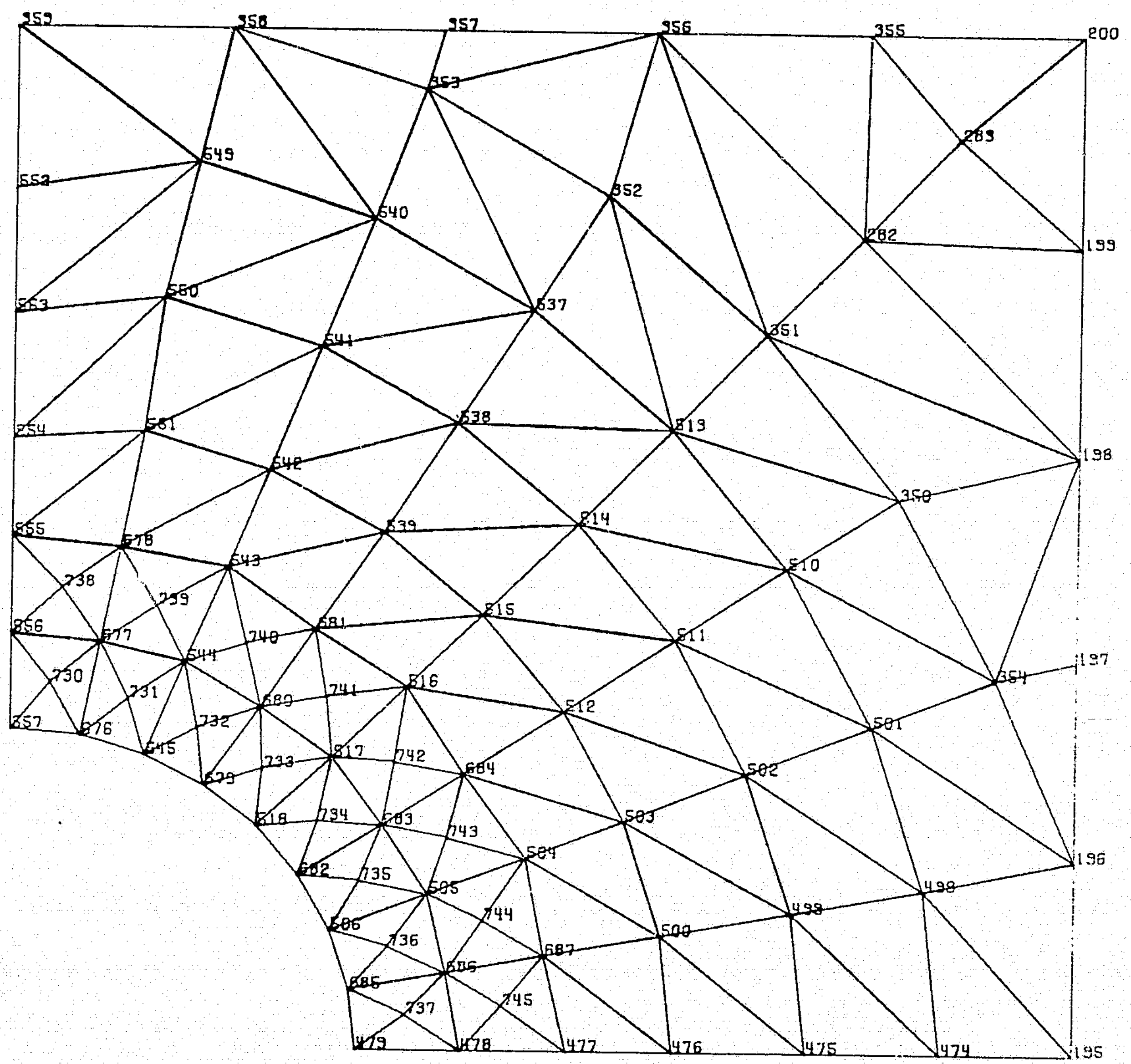


SPEC 7.1

NTF 9X12 DOOR REINF.
OUTER RING

0 19
SCALE

Figure 6

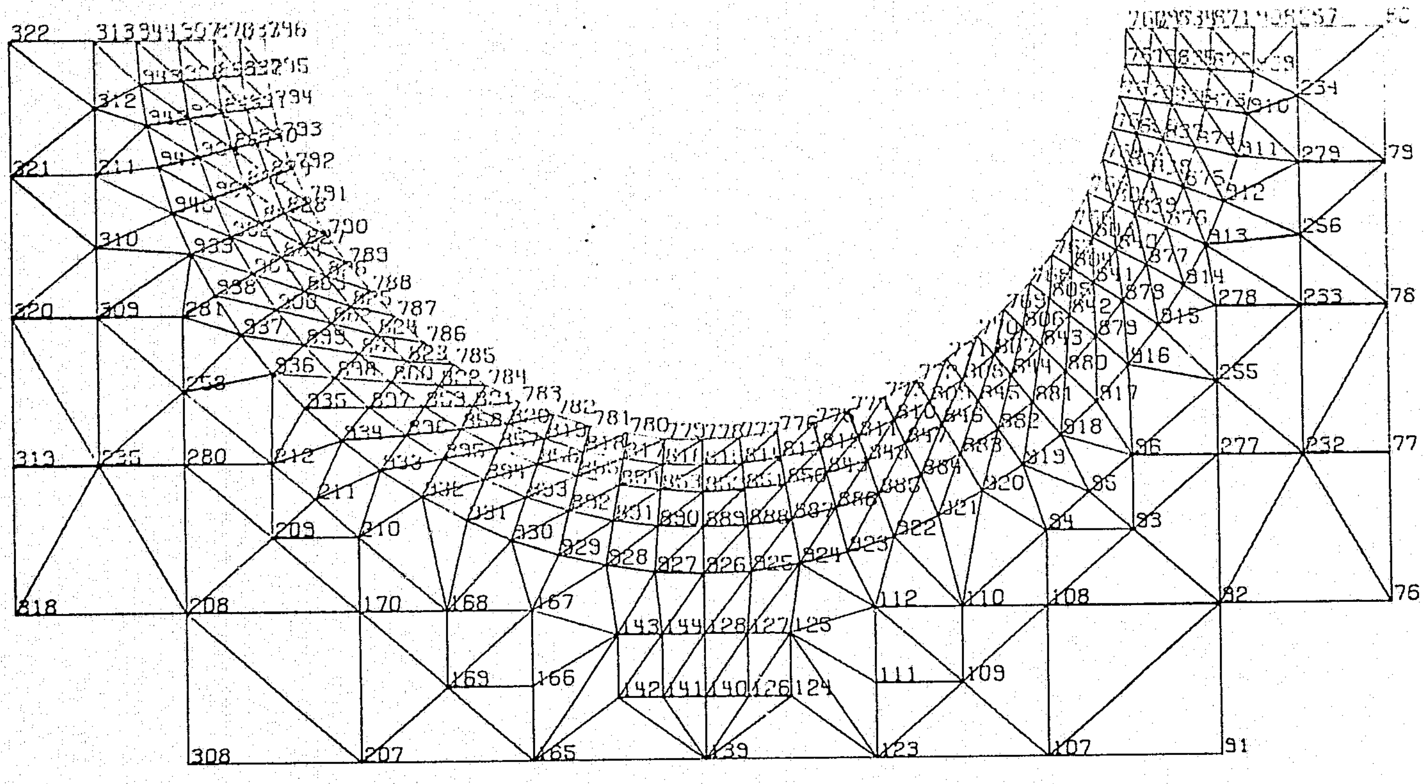


SPEC
8.1

NTF 9 X 12 REINF
CENTER TRIANGLES

0 6
SCALE

Figure 7



SPEC 9.1

9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

0 24
SCALE

Figure 8

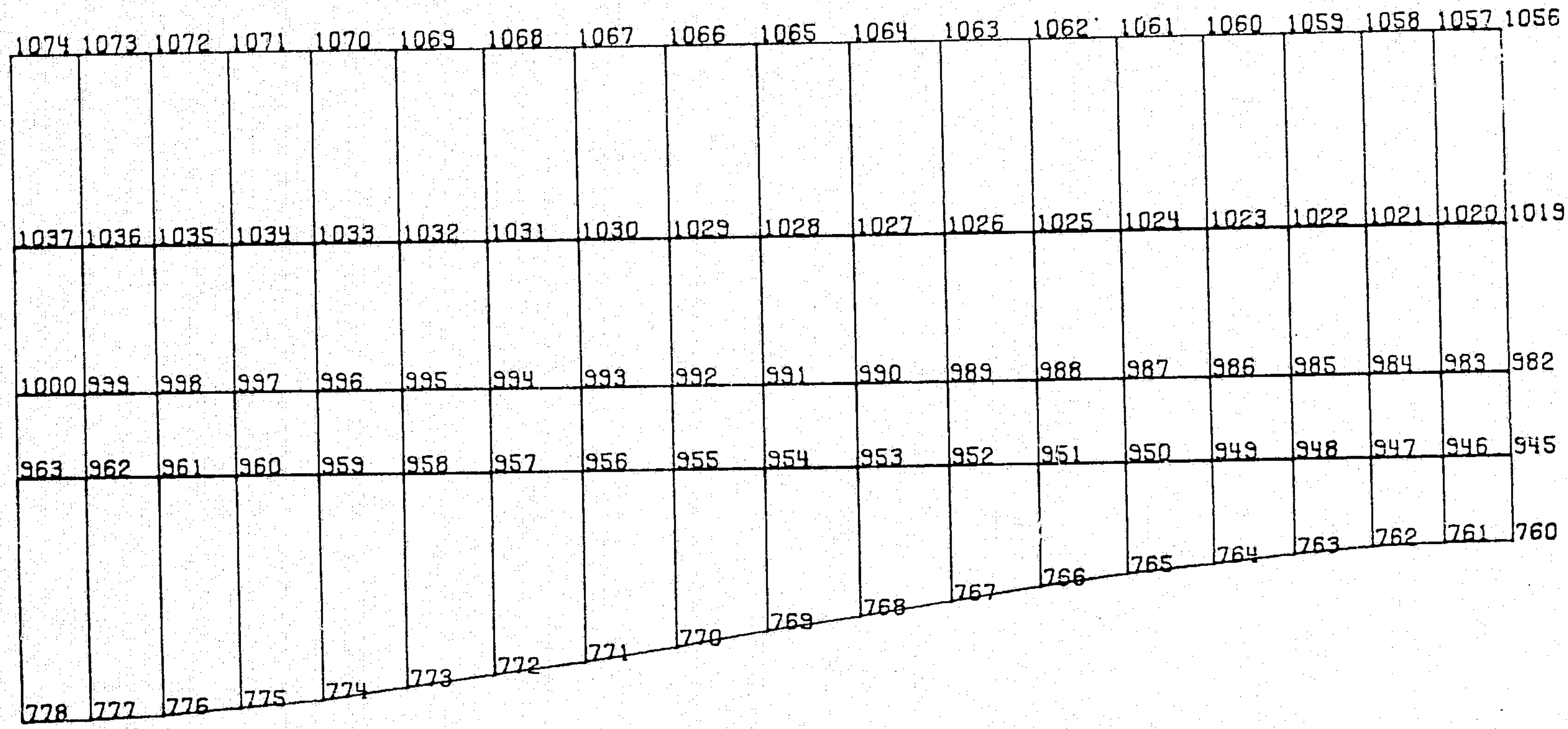
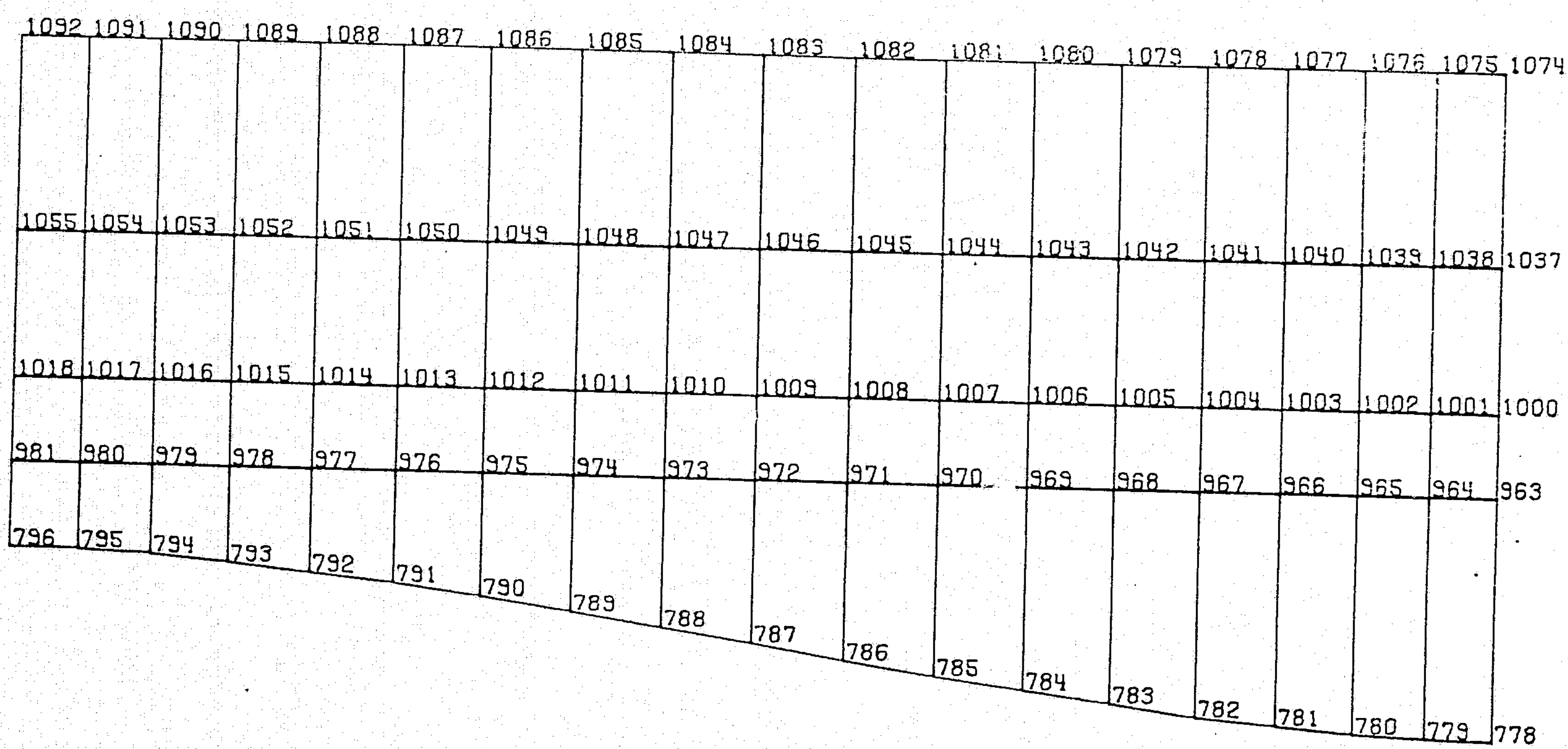


Figure 9

SPEC 10.1

9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 1
SCALE

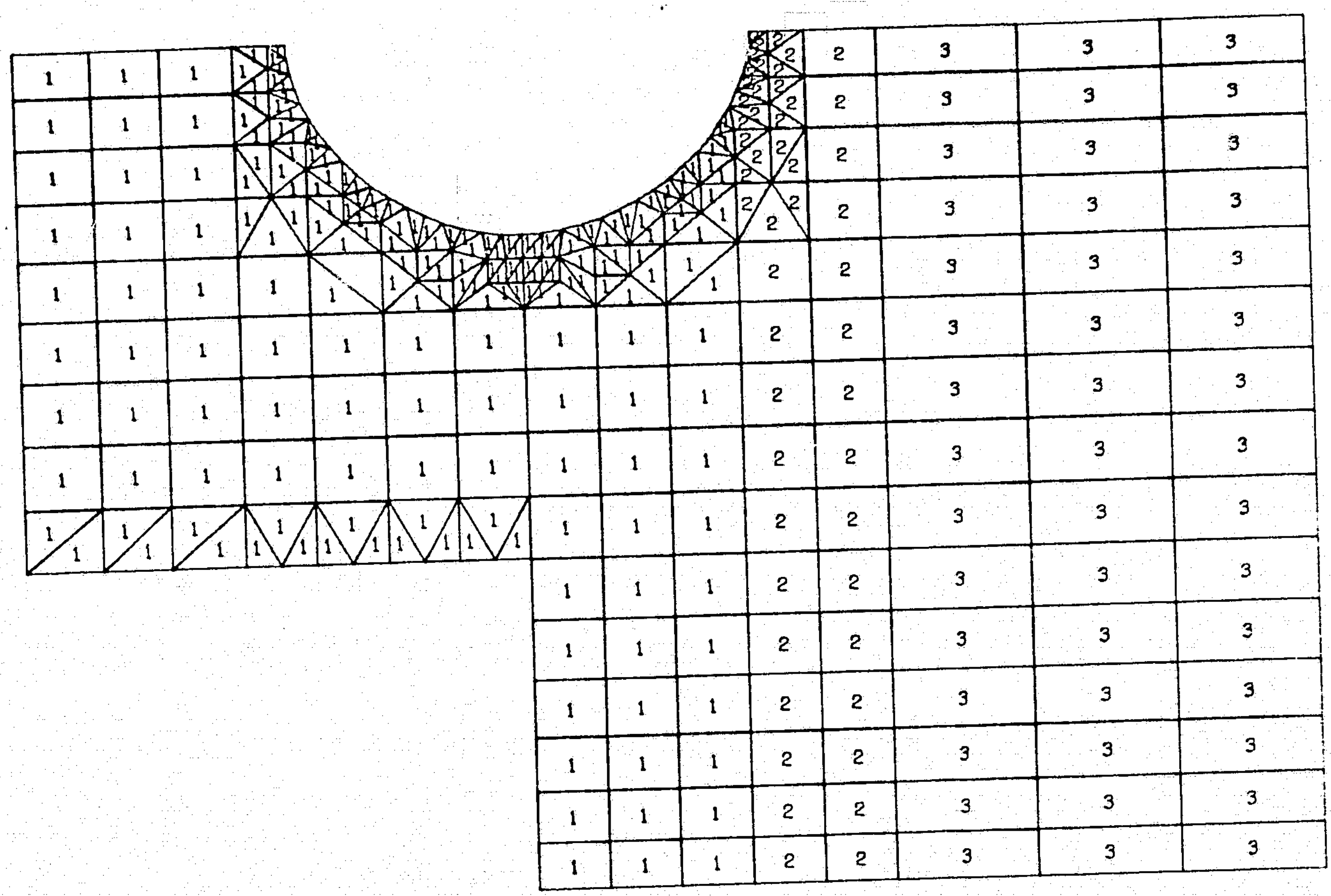


SPEC
11.1

9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

0 11
SCALE

Figure 10



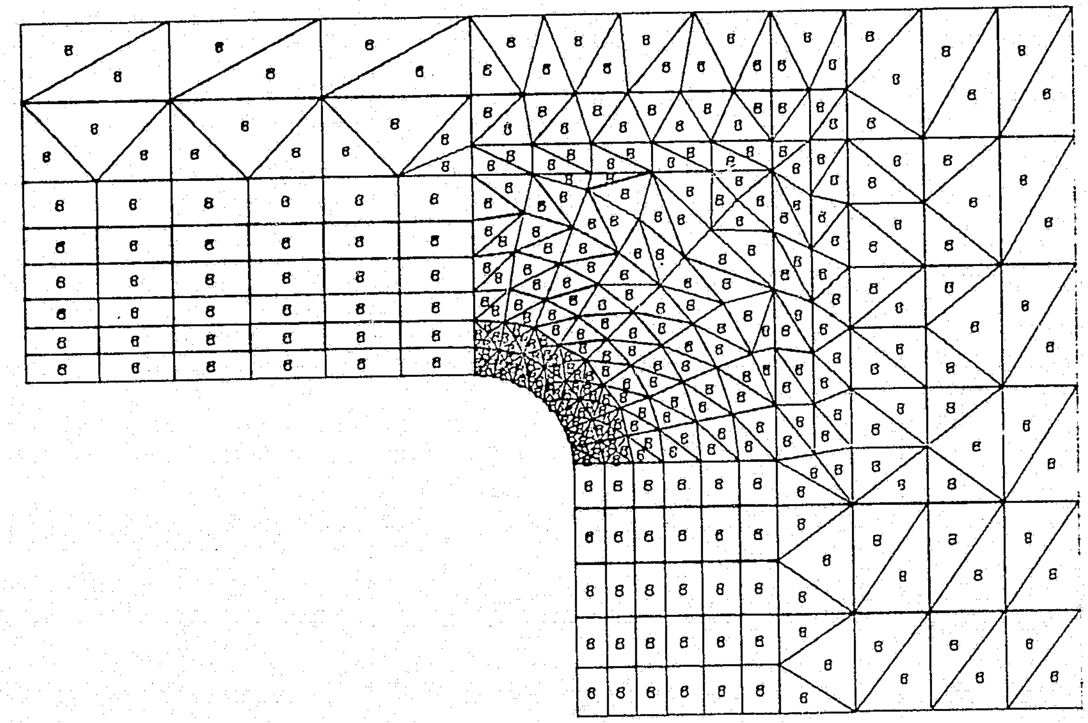
SPEC
3.1

NTF 9 X 12 ACCESS OPENING
SHELL

0 5
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 11



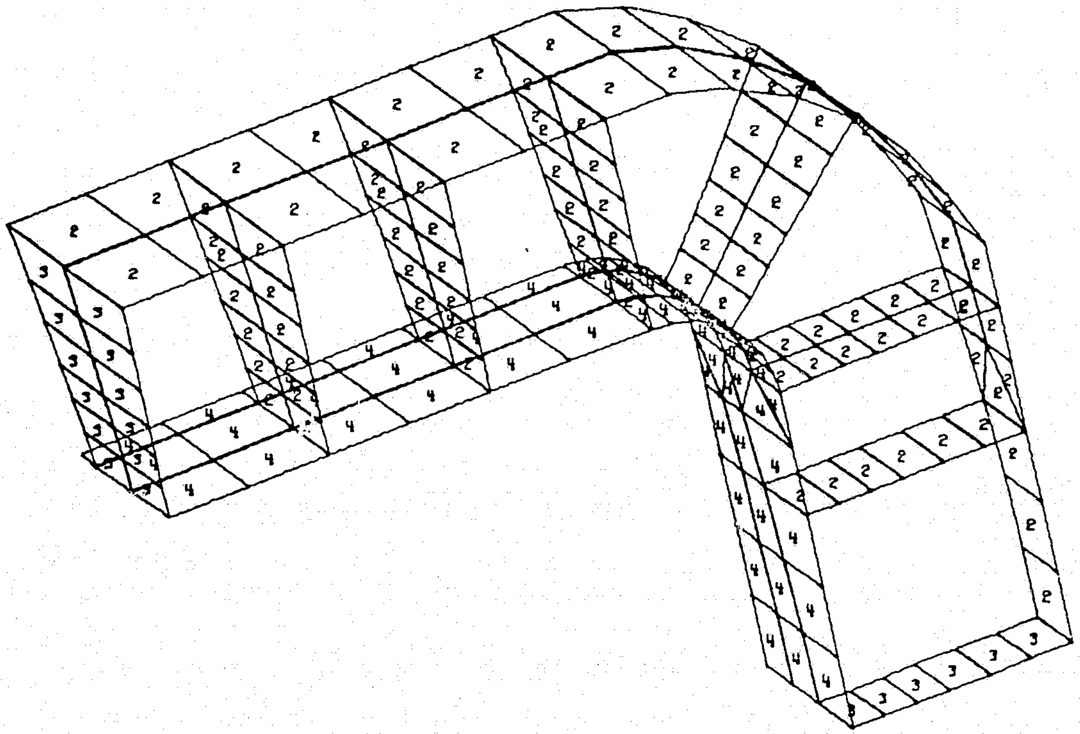
SPEC 4.1

NTF 9 X 12 ACCESS OPENING SHELL

0 SCALE 21

ELEMENT SECTION PROPERTY GROUPS

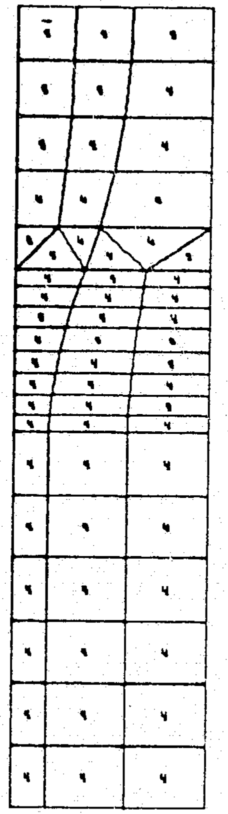
Figure 12



SPEC 5.1 NTF 9X12 ACESS OPENING GUSSET 0 18 SCALE

Figure 13

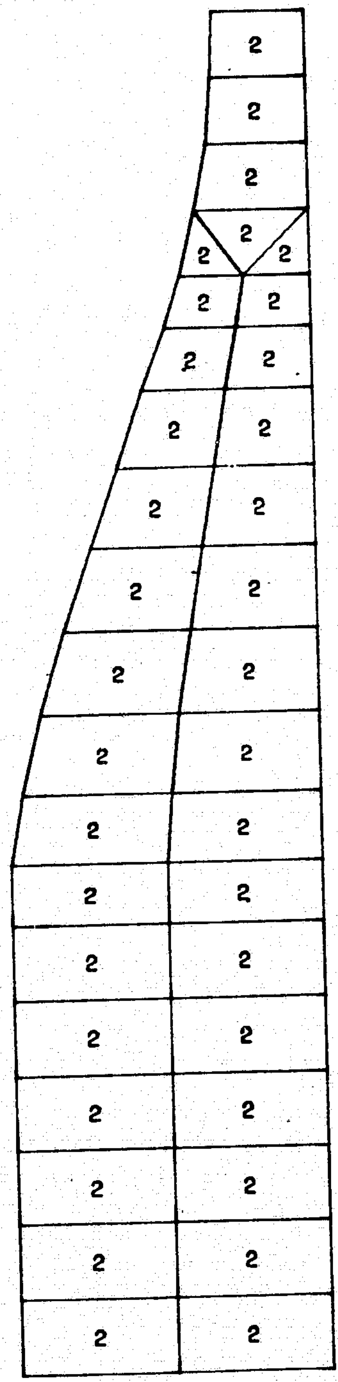
ENT SECTION PROPERTY GROUPS



SPEC 6.1 NTF 8X12 REINF. INNER RING

0 ______ 14
SCALE

Figure 14



ELEMENT SECTION PROPERTY GROUPS

0 SCALE 19

-SPEC
7.1

NTF 9X12 DOOR REINF.
OUTER RING

Figure 15

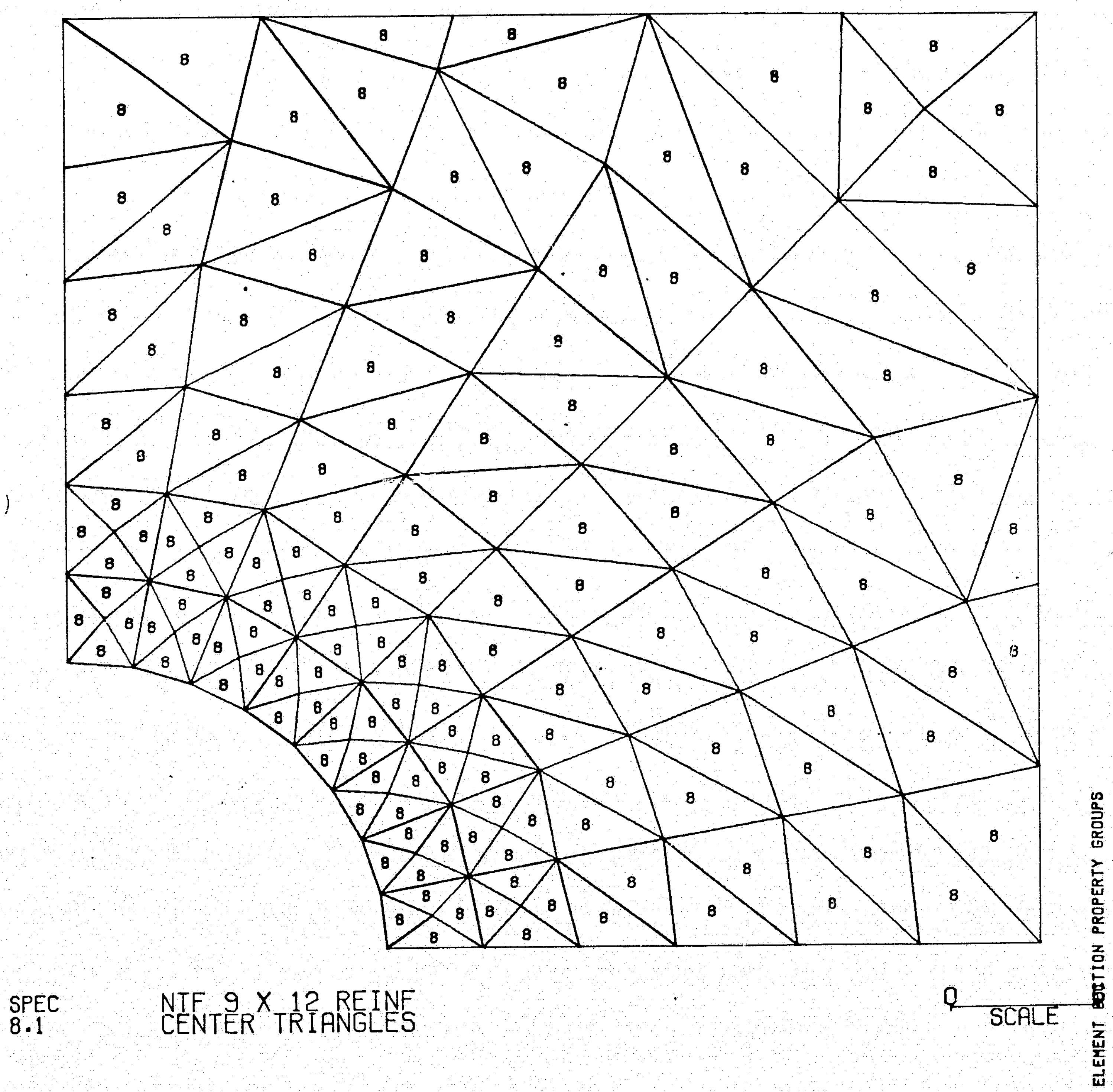
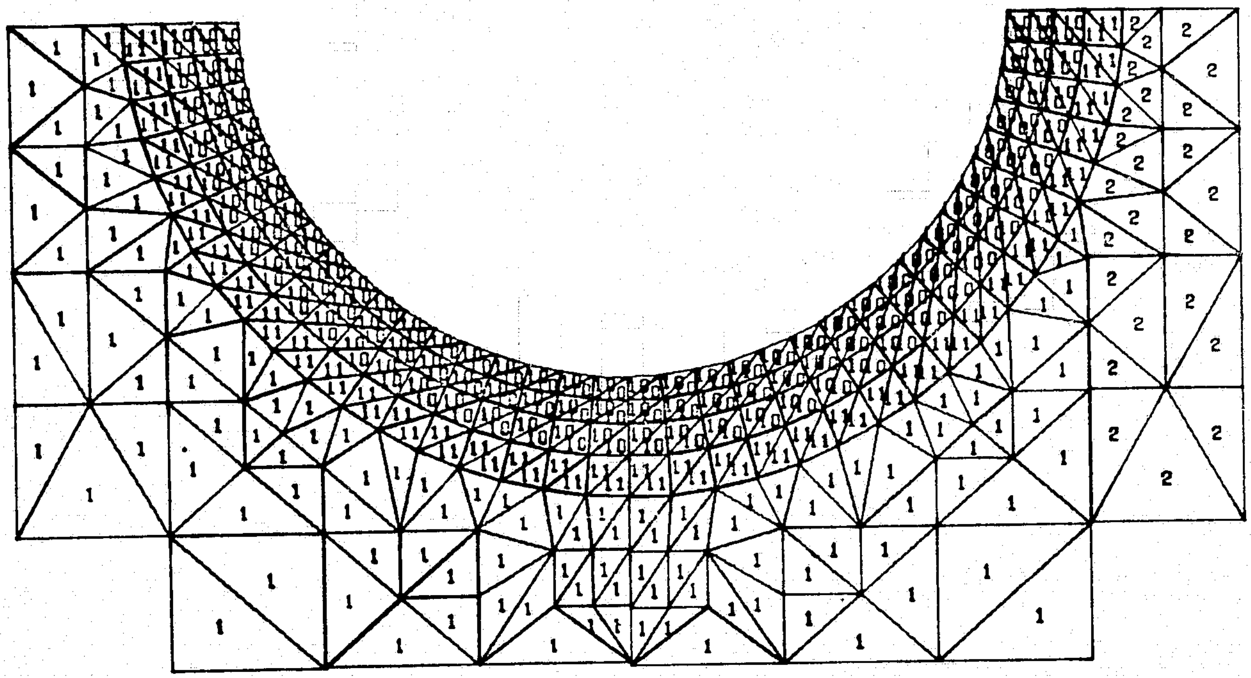

SPEC
8.1
NTF 9 X 12 REINF
CENTER TRIANGLES
0
SCALE
ELEMENT SECTION PROPERTY GROUPS

Figure 16



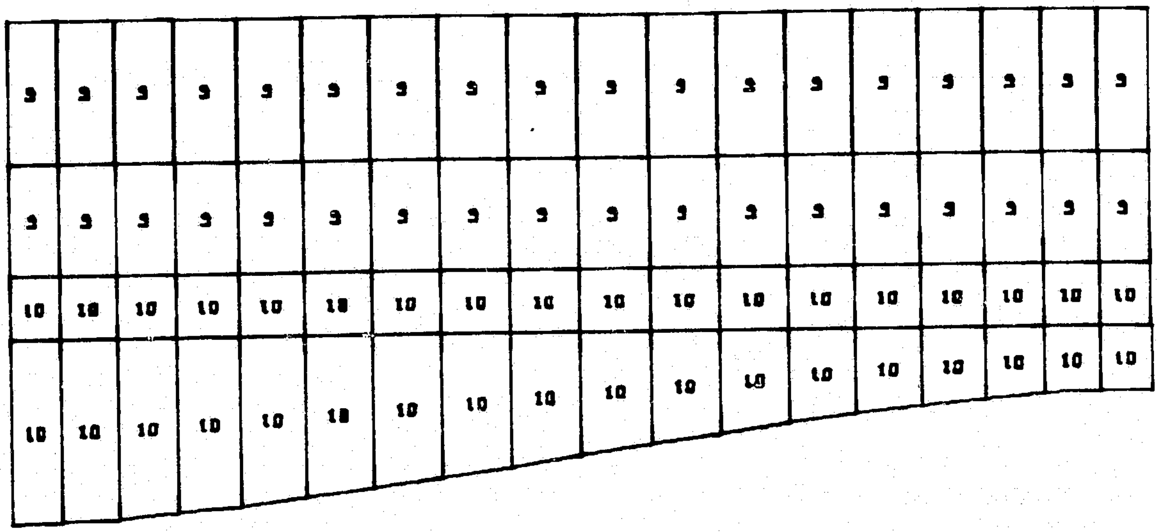
SPEC 9.1

9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

0 24
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 17



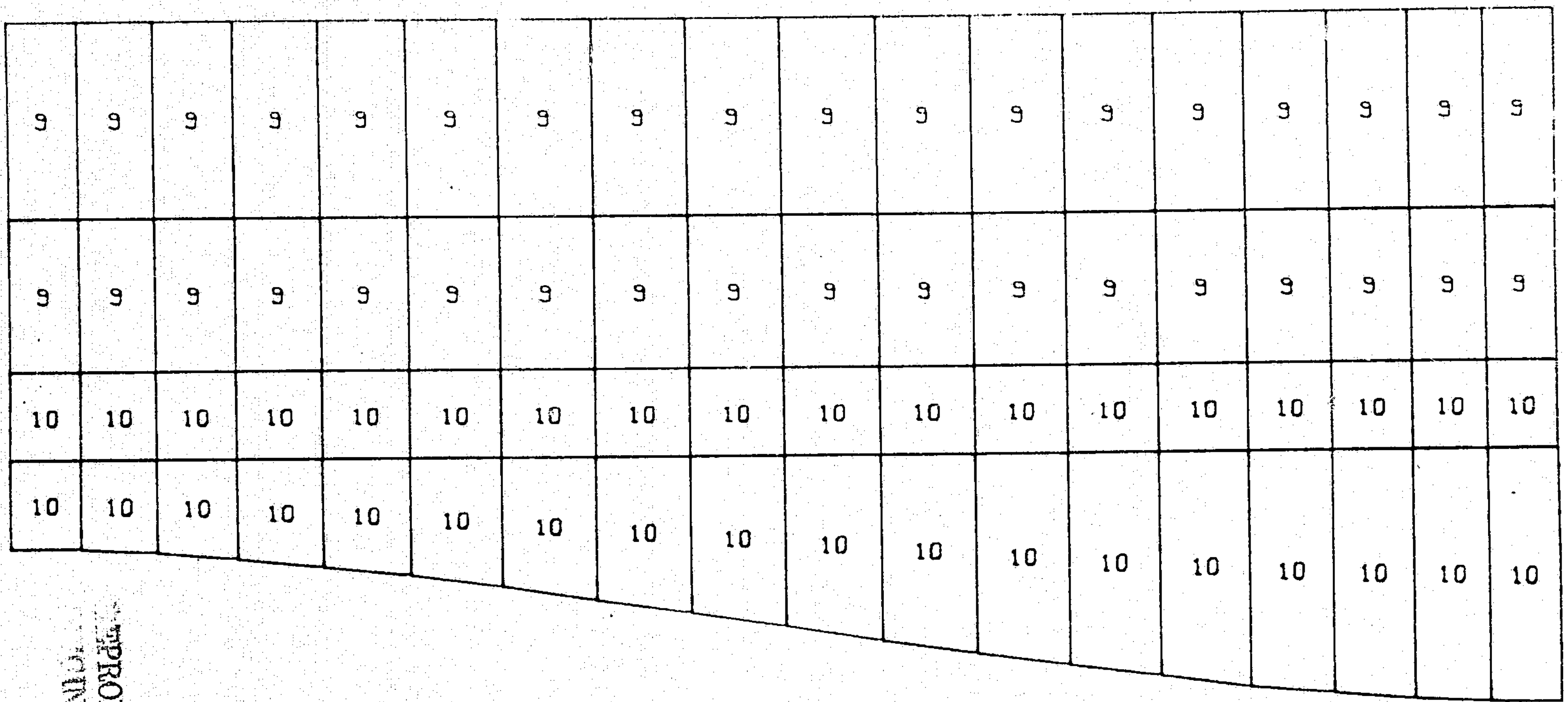
SPEC
10.1

9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 SCALE 11

MENT SECTION PROPERTY GROUPS

Figure 18



ELEMENT SECTION PROPERTY GROUPS

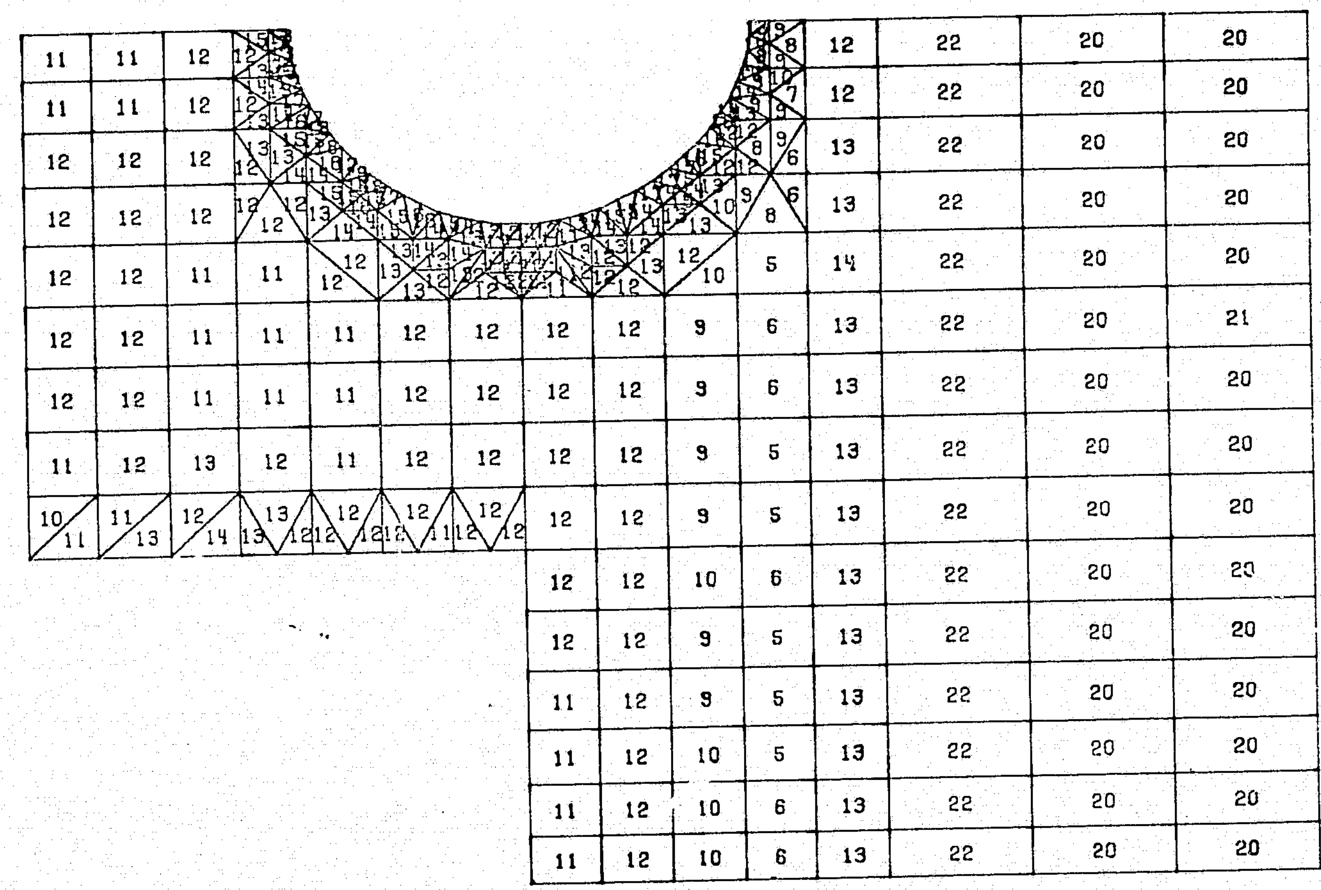
Figure 19

SPEC 11.1 9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

0 11
SCALE

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



SPEC 3.1

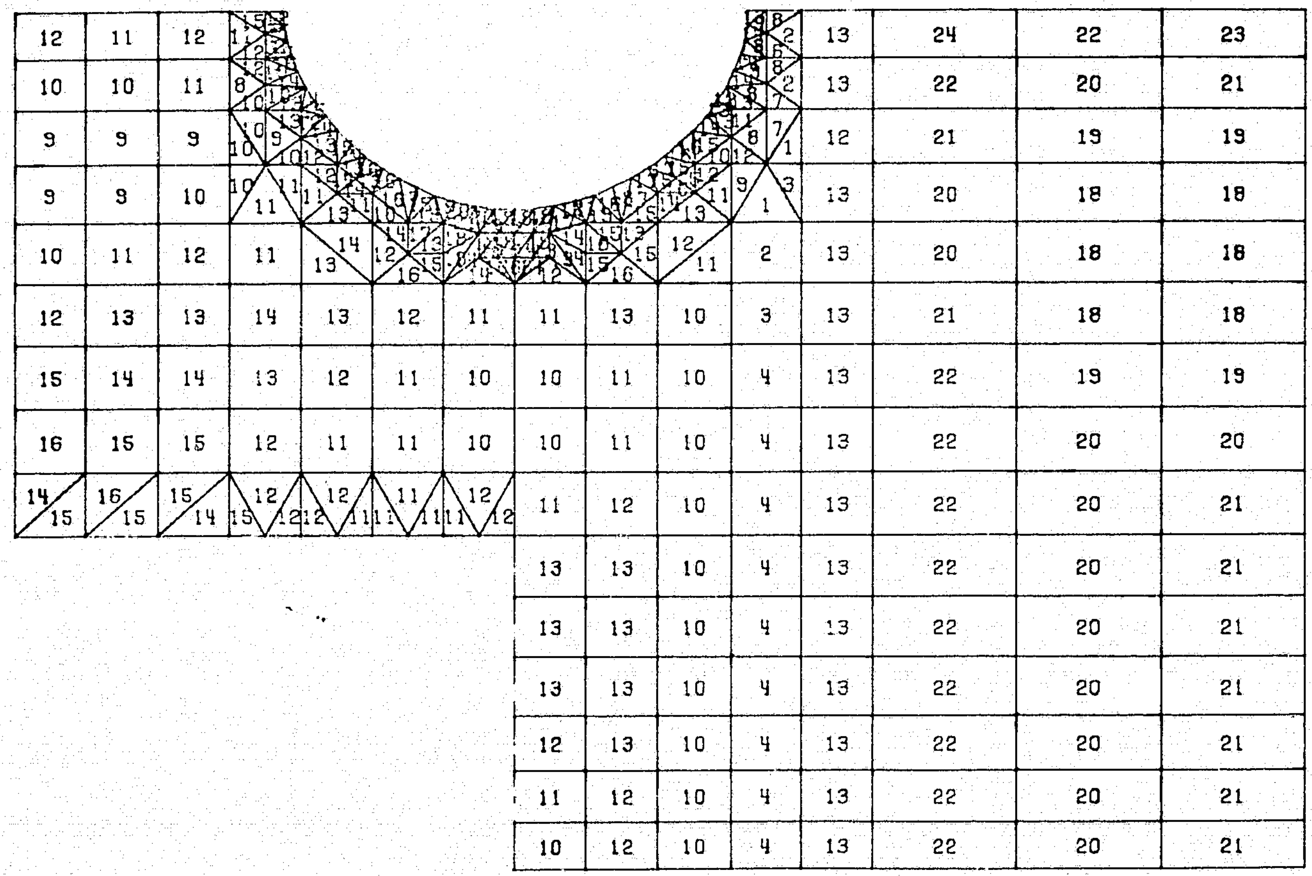
NTF 9 X 12 ACCESS OPENING
SHELL

0 55
SCALE

Figure 20

10 / 1 / 1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



SPEC 3.1

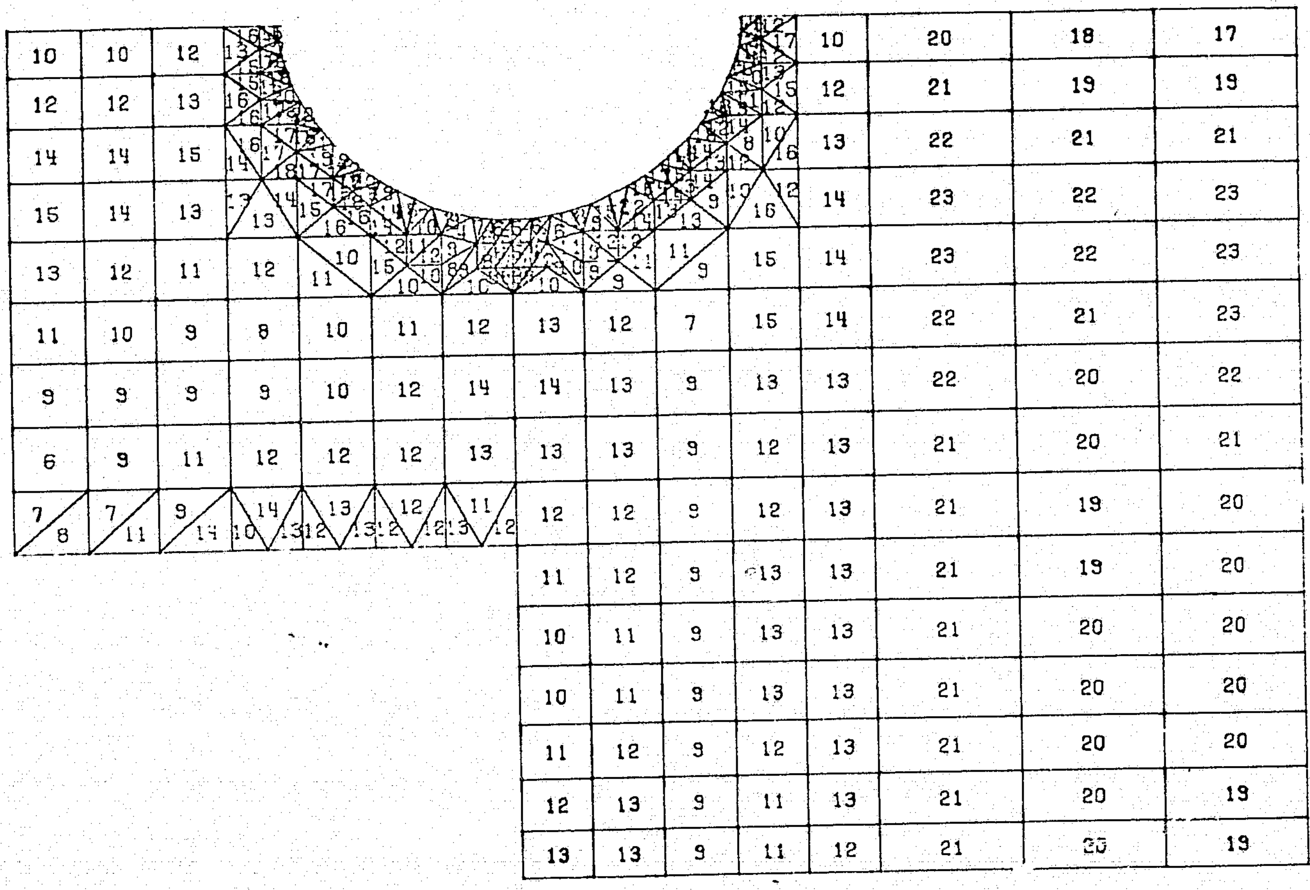
NTF 9 X 12 ACCESS OPENING SHELL

0 55 SCALE

Figure 21

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2



SPEC 3.1

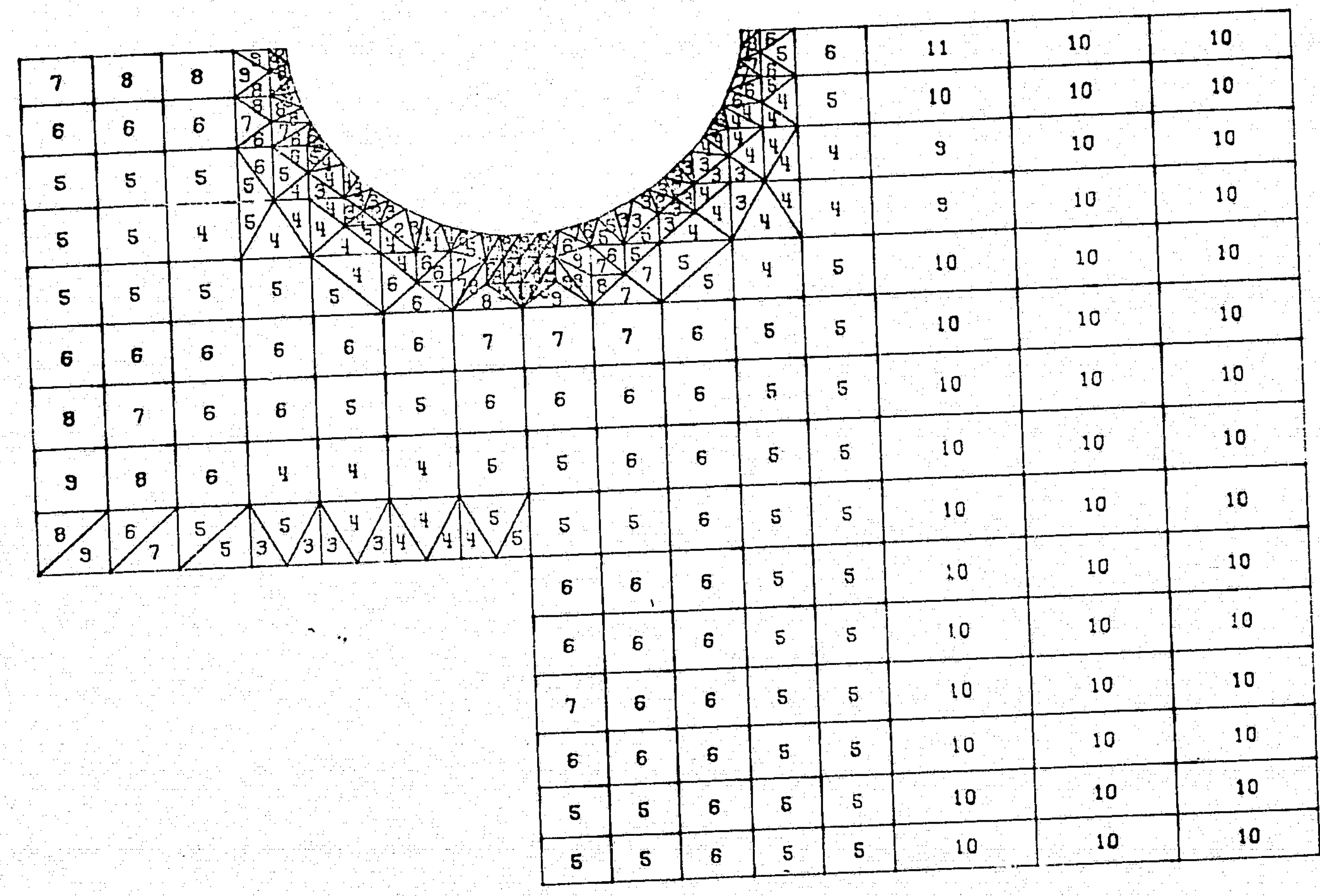
NTF 9 X 12 ACCESS OPENING SHELL

0 55 SCALE

Figure 22

10/1/1

DISPLAY= PS2 /1COC , NODE= 1, SURFACE= 0



0 55
SCALE

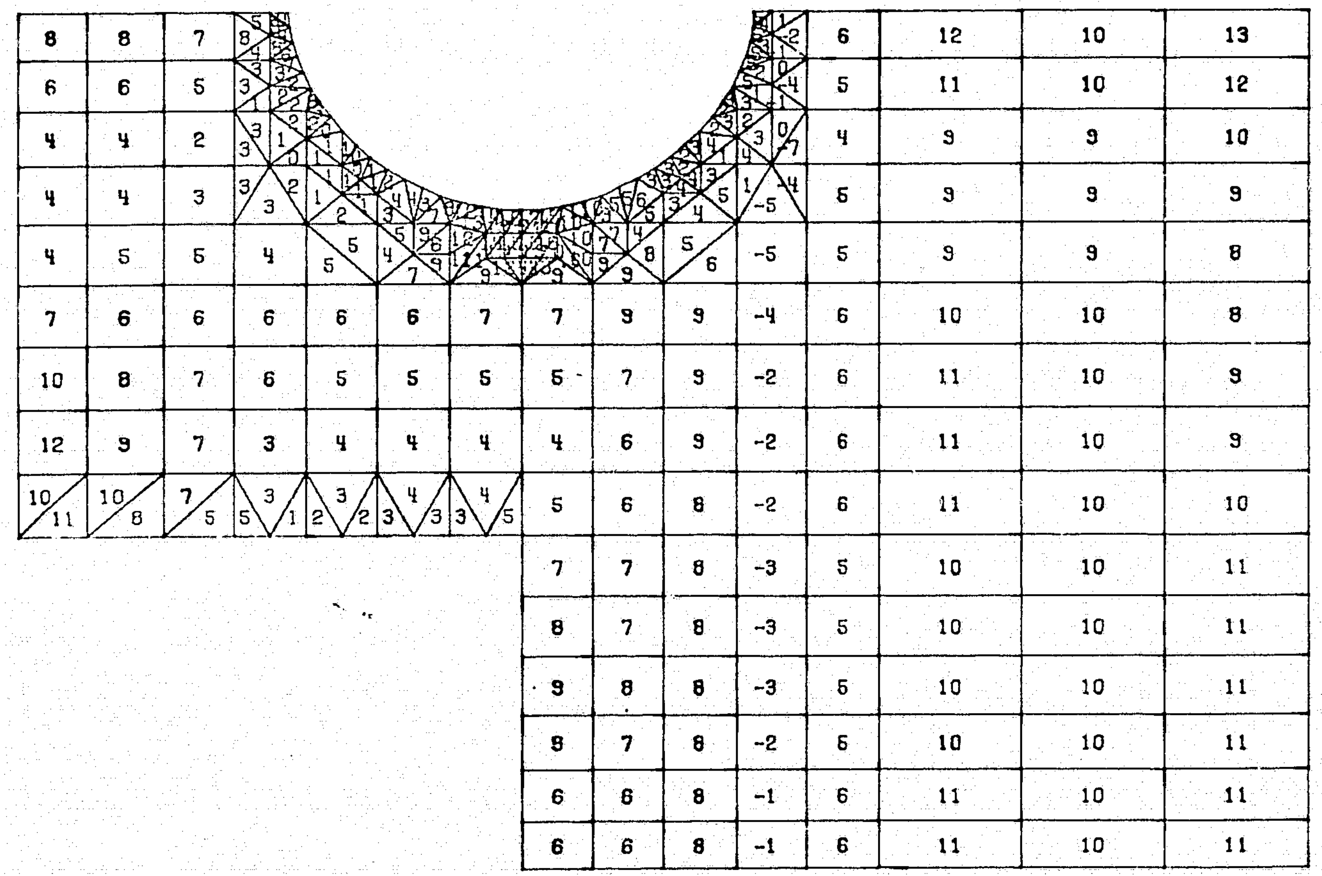
SPEC
3.1

NTF 9 X 12 ACCESS OPENING
SHELL

Figure 23

10 / 1 / 1

ISPLAY= PS2 /1000 , NODE= 1, SURFACE= 1



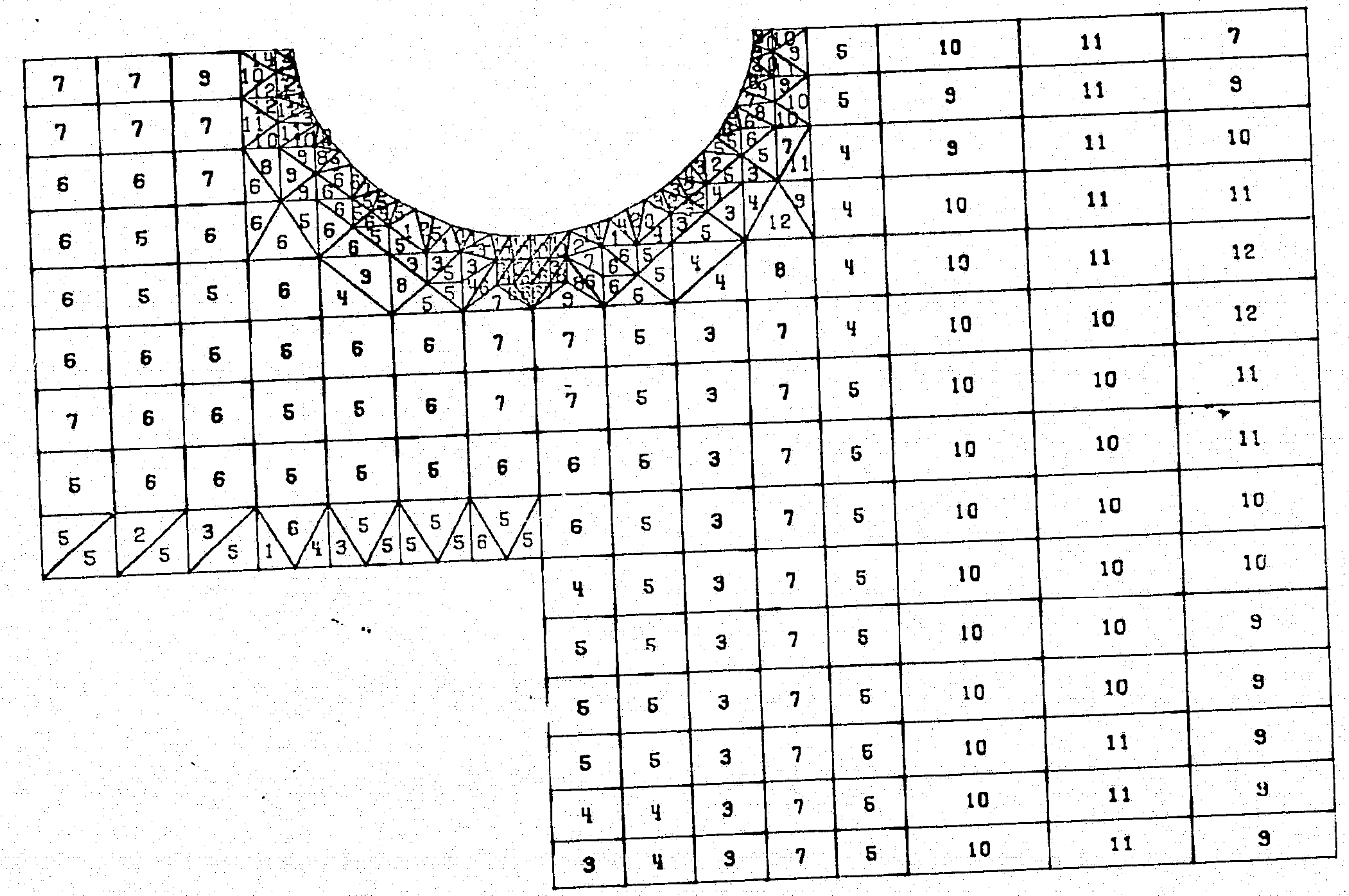
SPEC 3.1

NTF 9 X 12 ACCESS OPENING
SHELL

0 55
SCALE

Figure 24

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

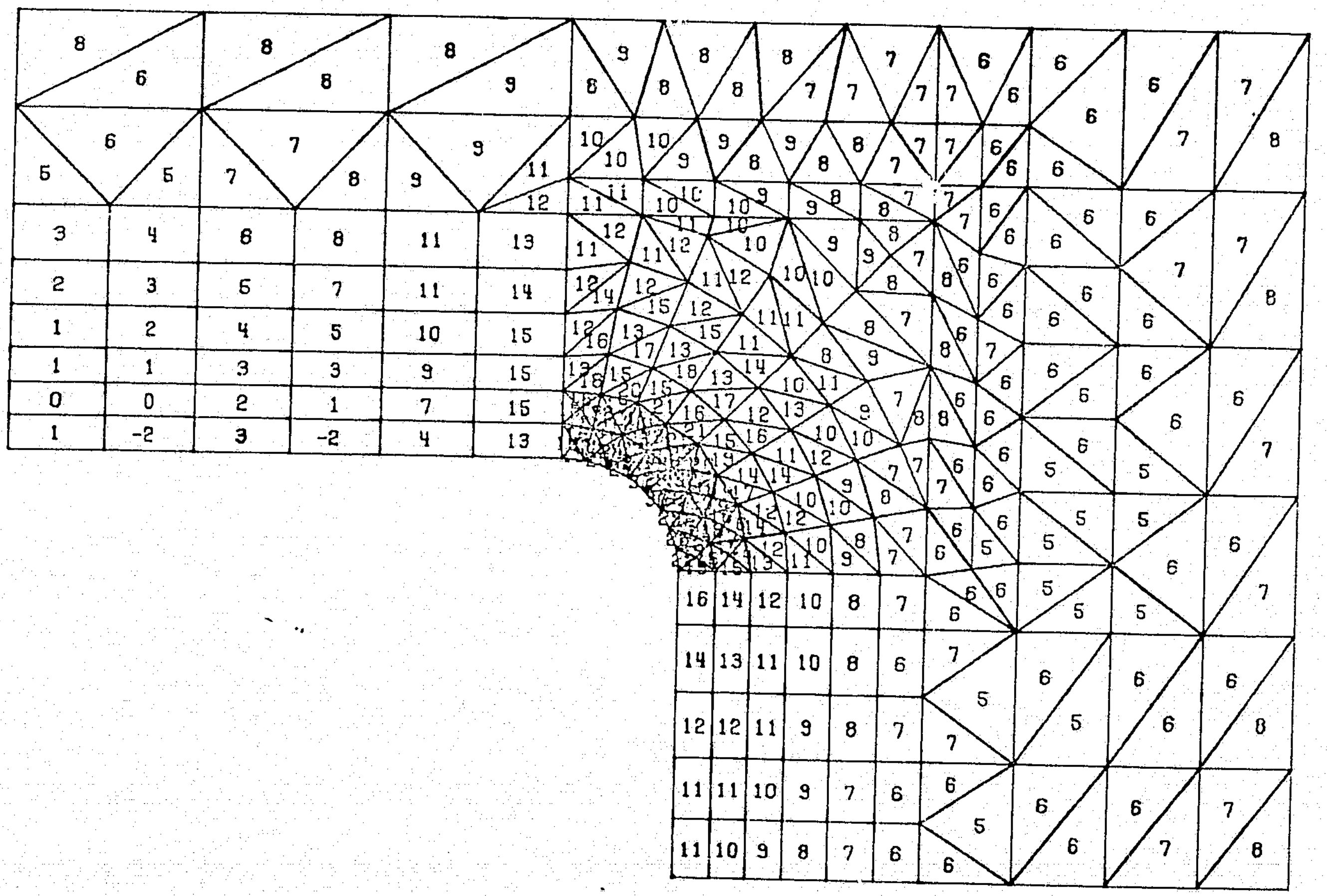


0 55
SCALE

SPEC 3.1 NTF 9 X 12 ACCESS OPENING SHELL

Figure 25

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 0 10/1/1

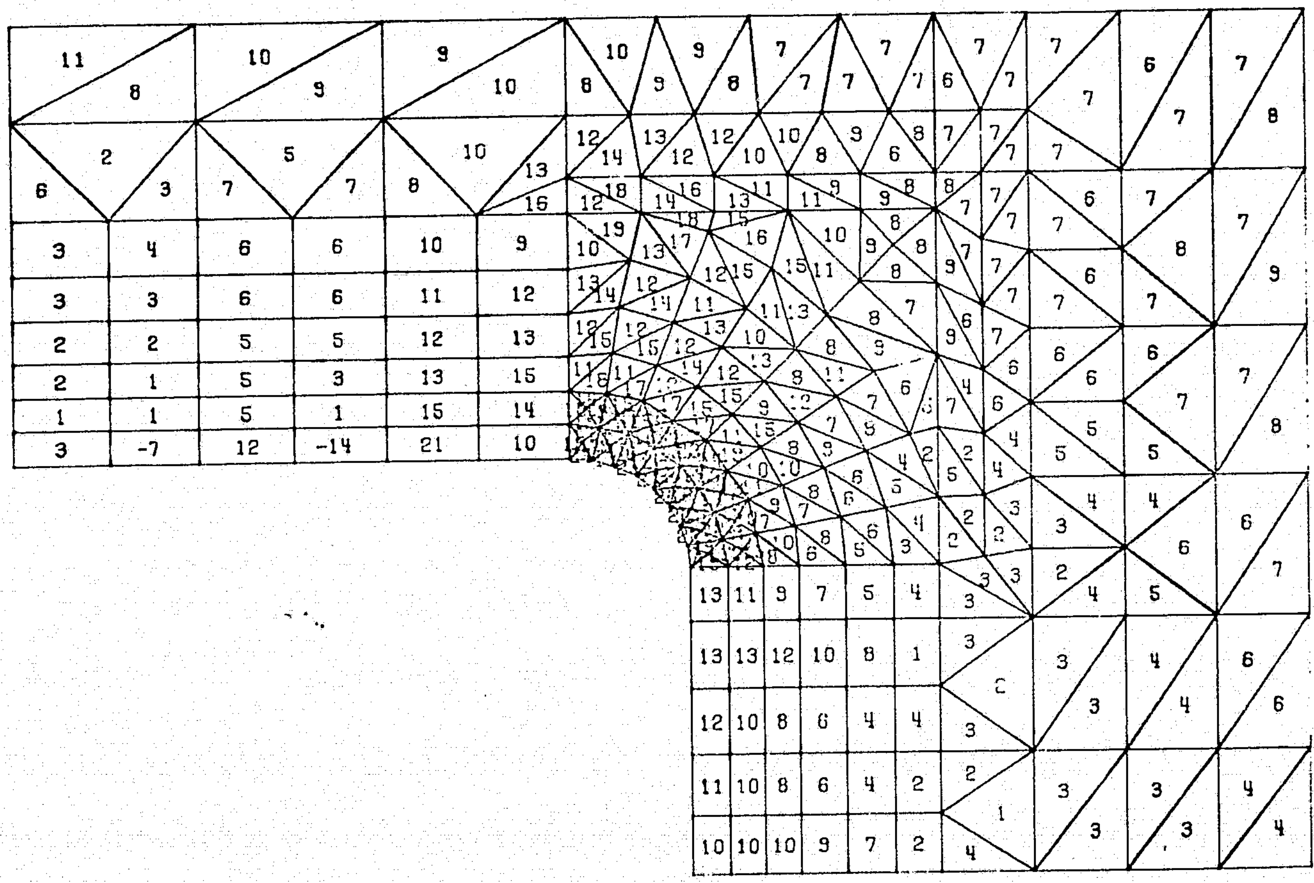


SPEC 4.1 NTF 9 X 12 ACCESS OPENING SHELL

0 21 SCALE

Figure 26

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



SPEC 4.1

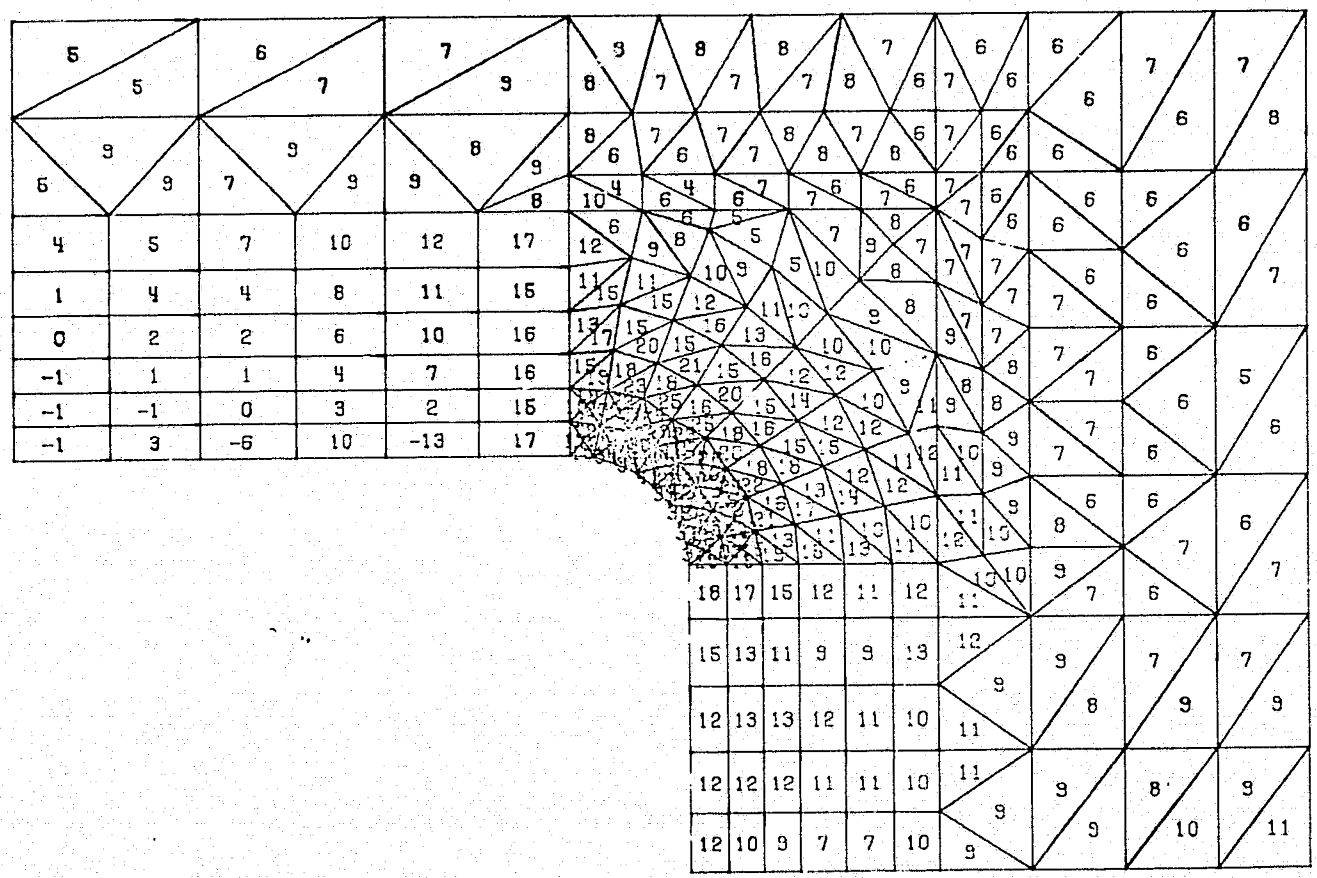
NTF 9 X 12 ACCESS OPENING SHELL

0 21 SCALE

Figure 27

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2



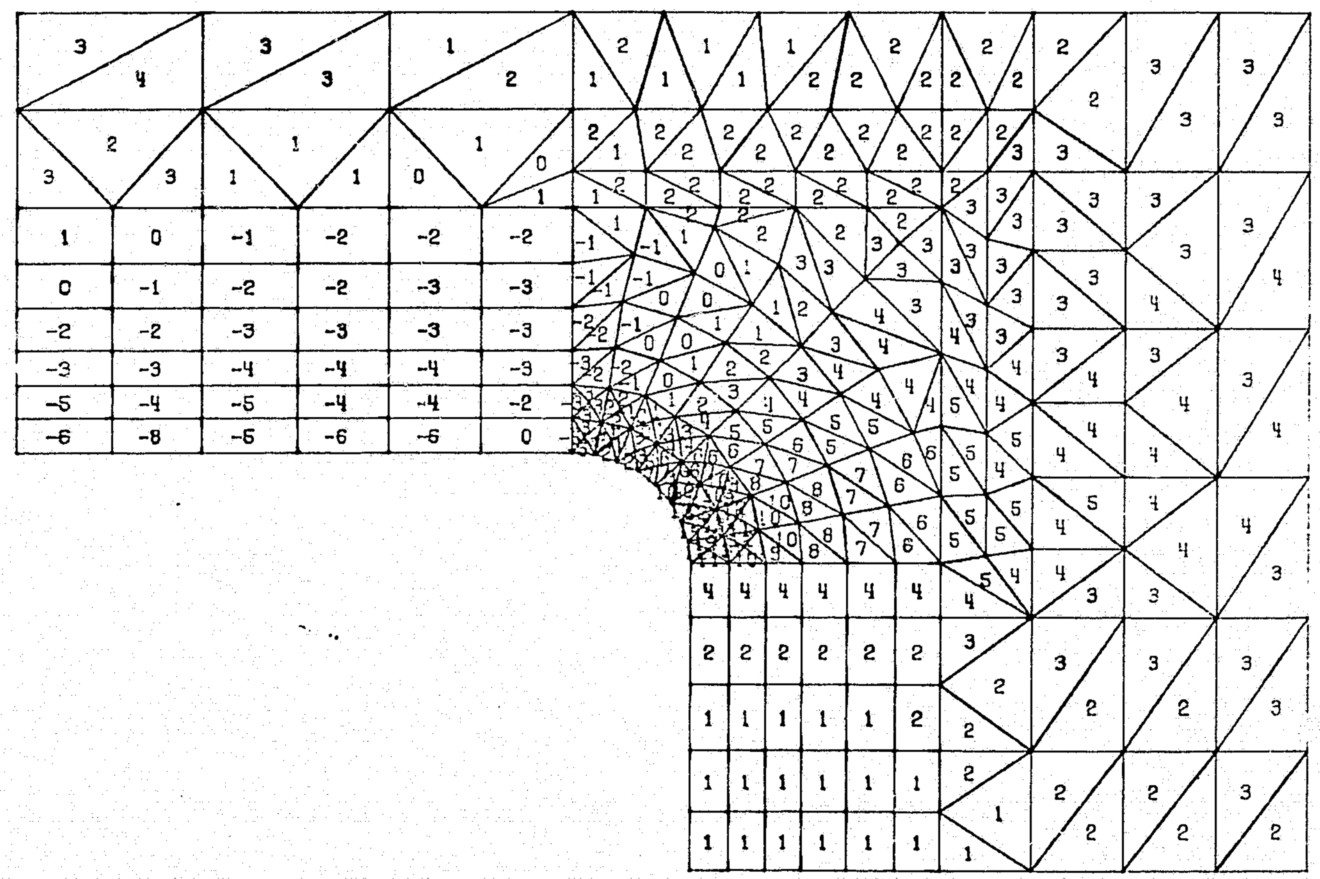
SPEC 4.1 NTF 9 X 12 ACCESS OPENING SHELL

0 SCALE 21

Figure 28

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

10/1/1



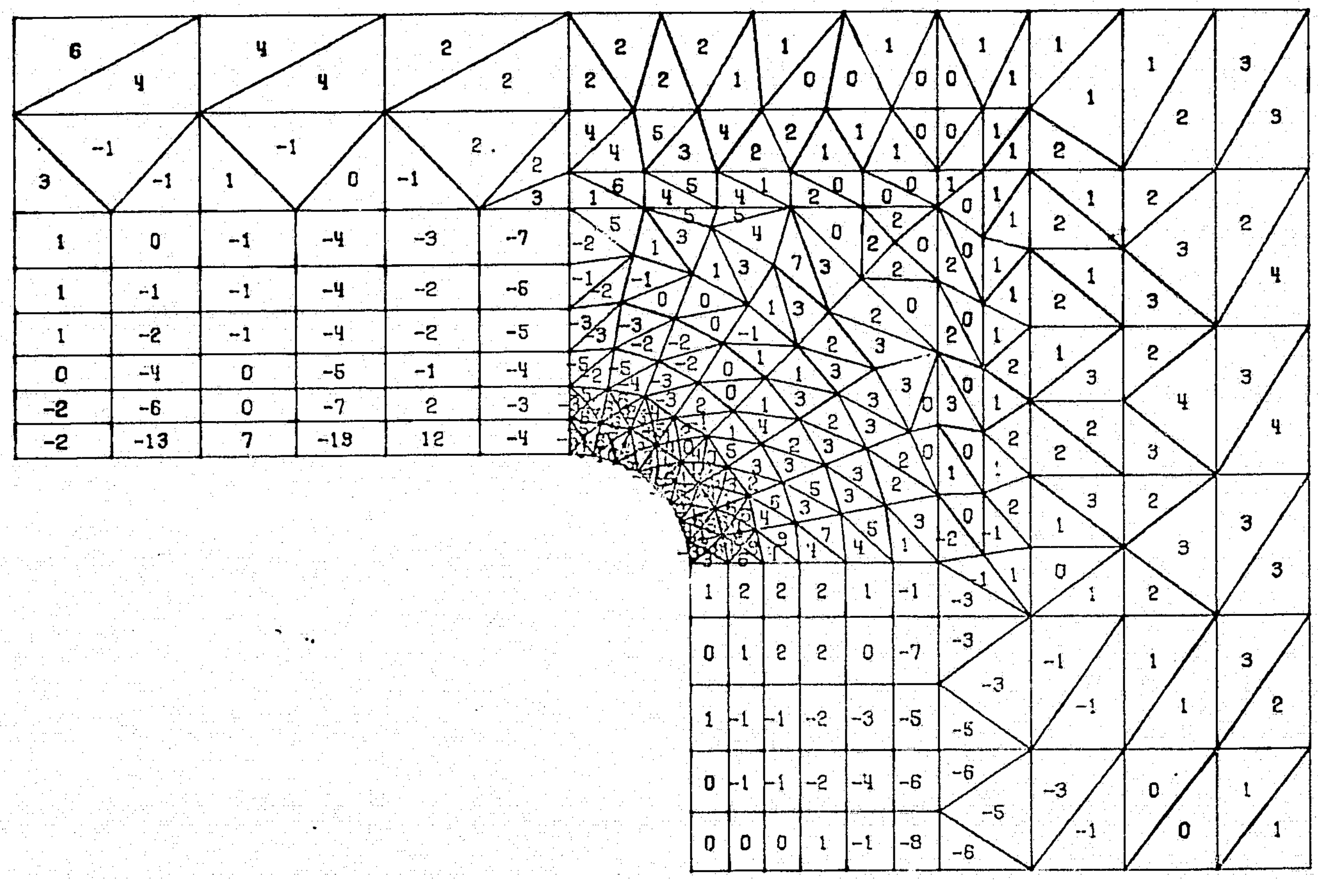
SPEC 4.1

NTF 9 X 12 ACCESS OPENING SHELL

0 21 SCALE

Figure 29

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1 10/1/1



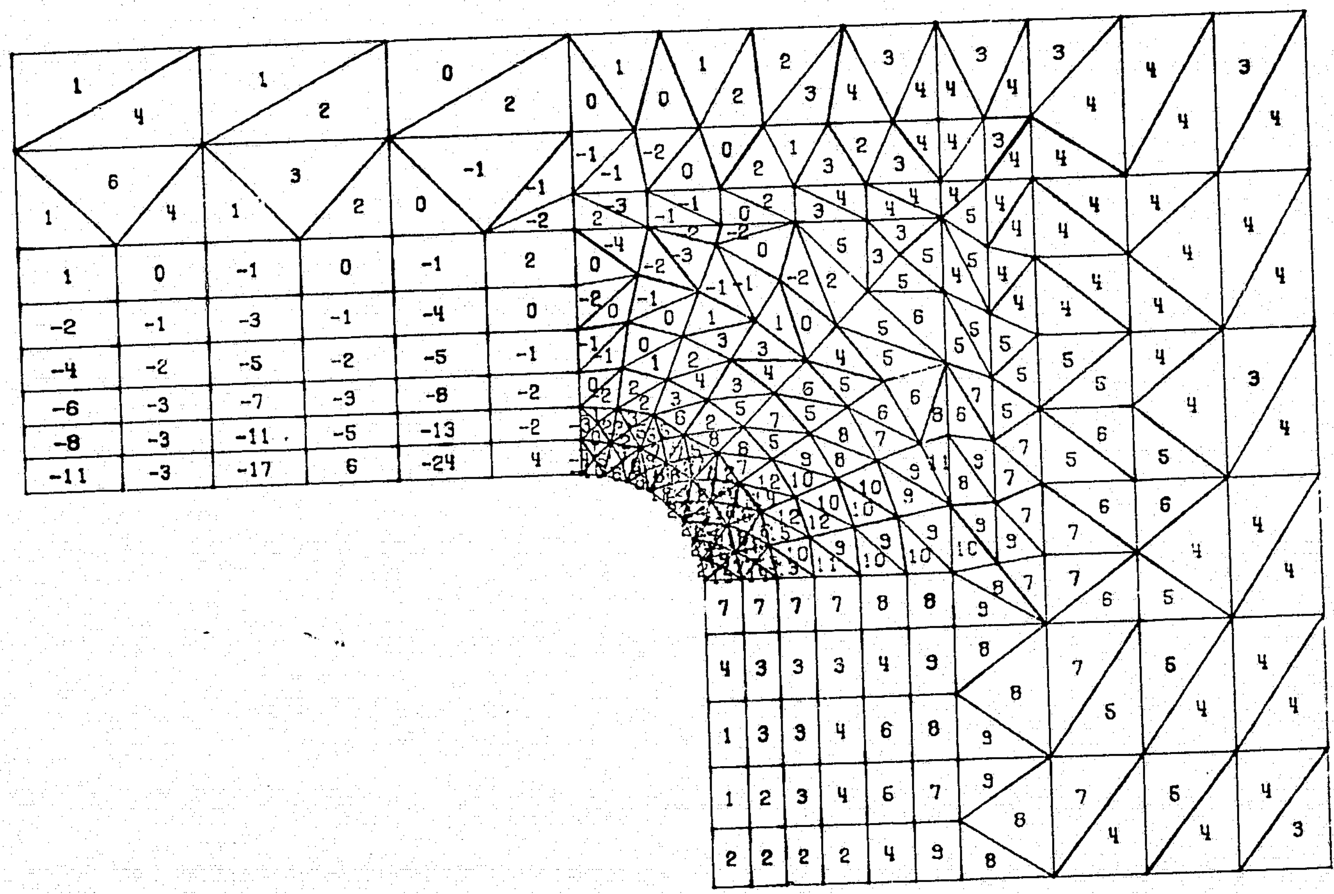
SPEC 4.1 NTF 9 X 12 ACCESS OPENING SHELL

0 21 SCALE

Figure 30

10/1/1

DISPLAY= PS2 /1000 , NODE= 1, SURFACE= 2



0 21
SCALE

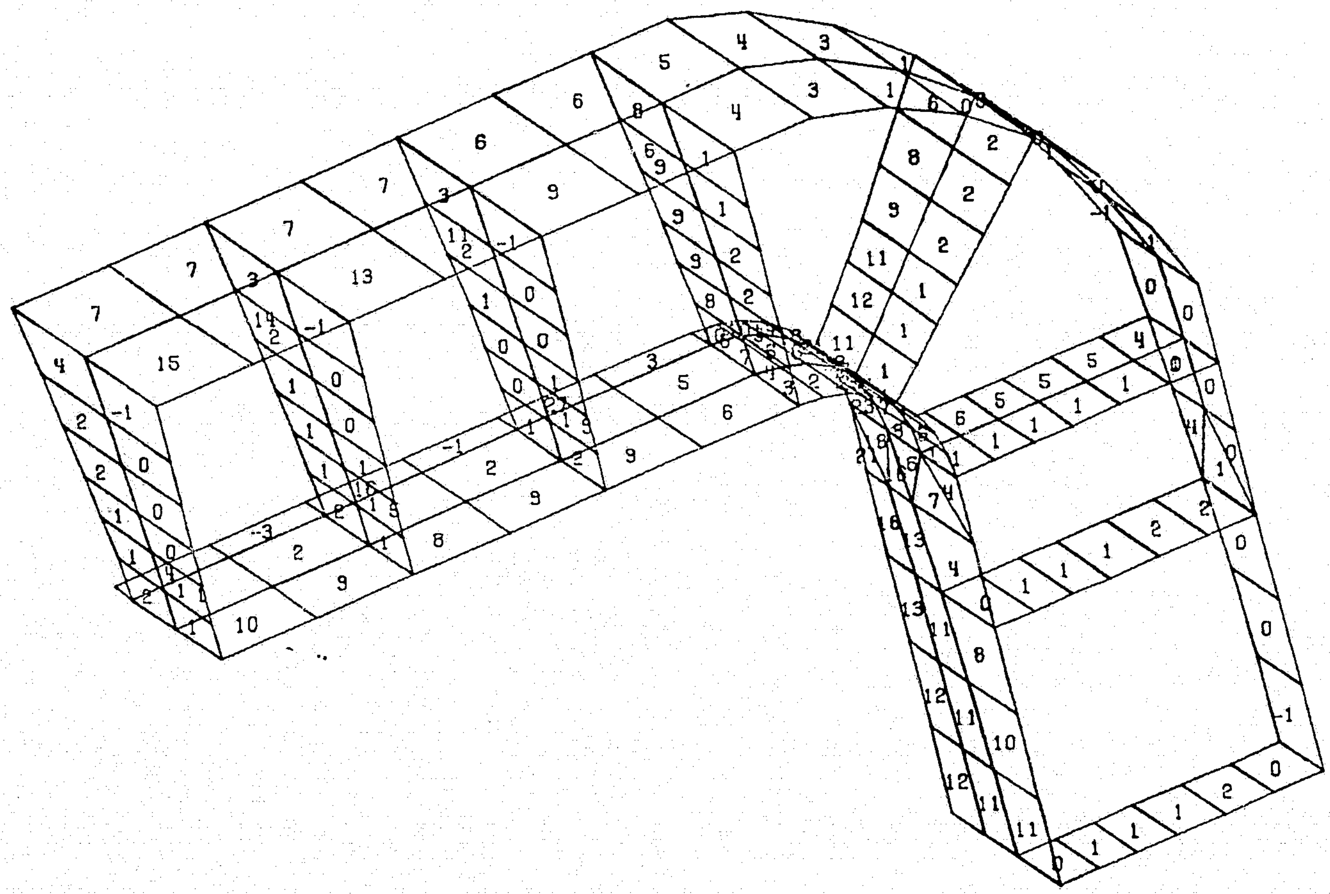
SPEC
4.1

NTF 9 X 12 ACCESS OPENING
SHELL

Figure 31

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



0 18
SCALE

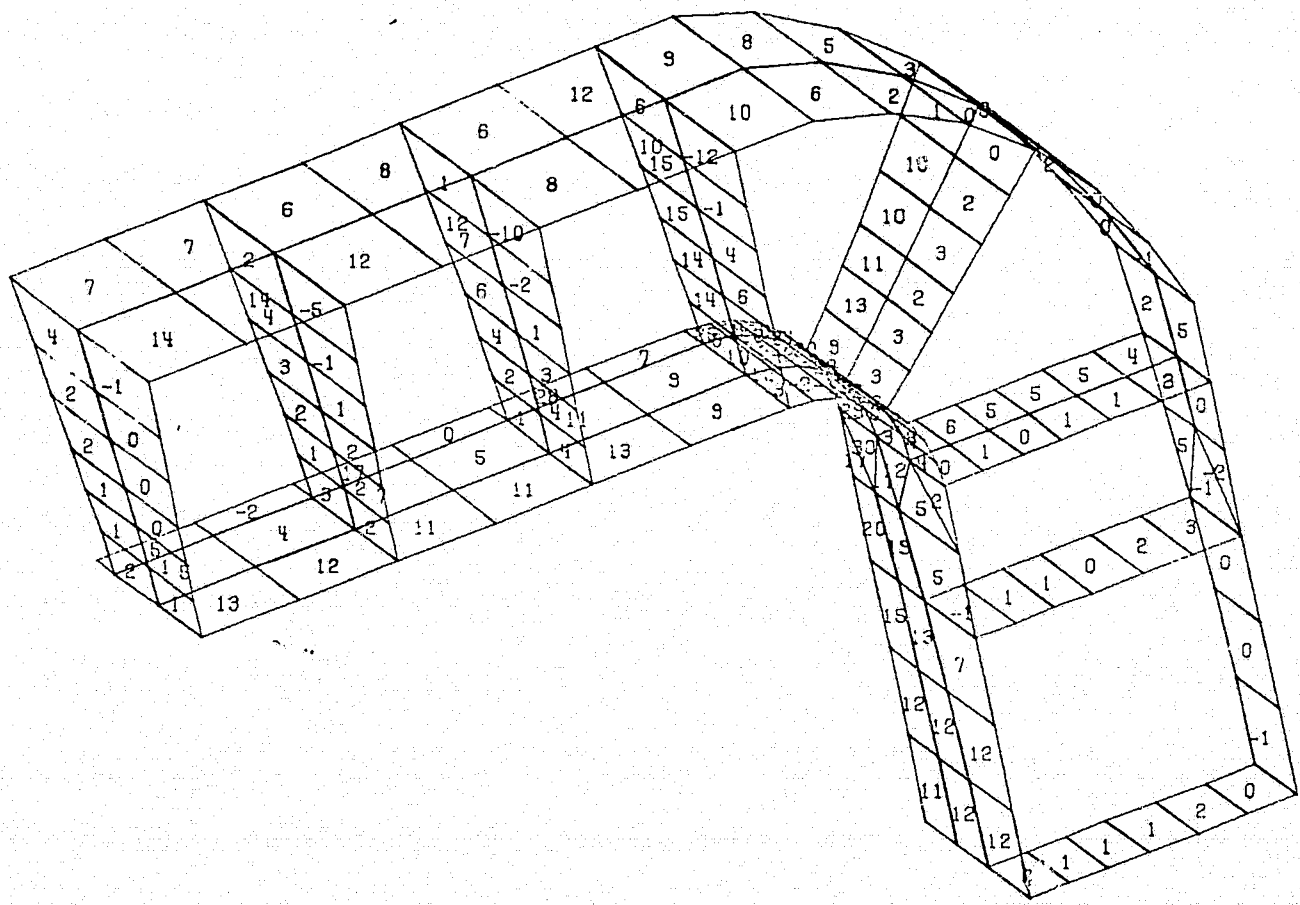
SPEC
5.1

NTF 9X12 ACESS OPENING
GUSSET

Figure 32

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 1



SPEC
5.1

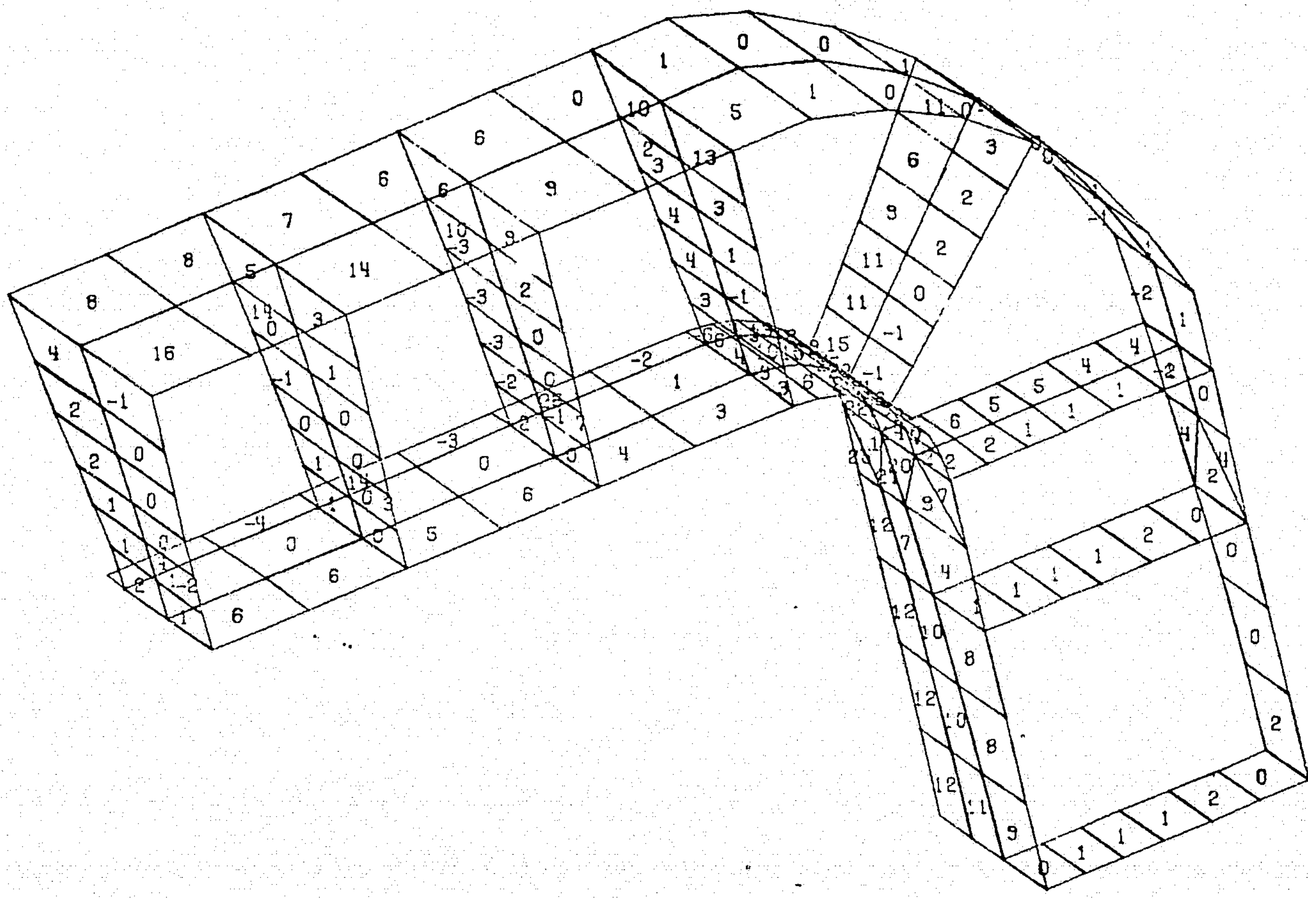
NTF 9X12 ACESS OPENING
GUSSET

0 18
SCALE

Figure 33

10/1/1

)ISPLAY= PS1 /1000 , NCDE= 1, SURFACE= 2



0 18
SCALE

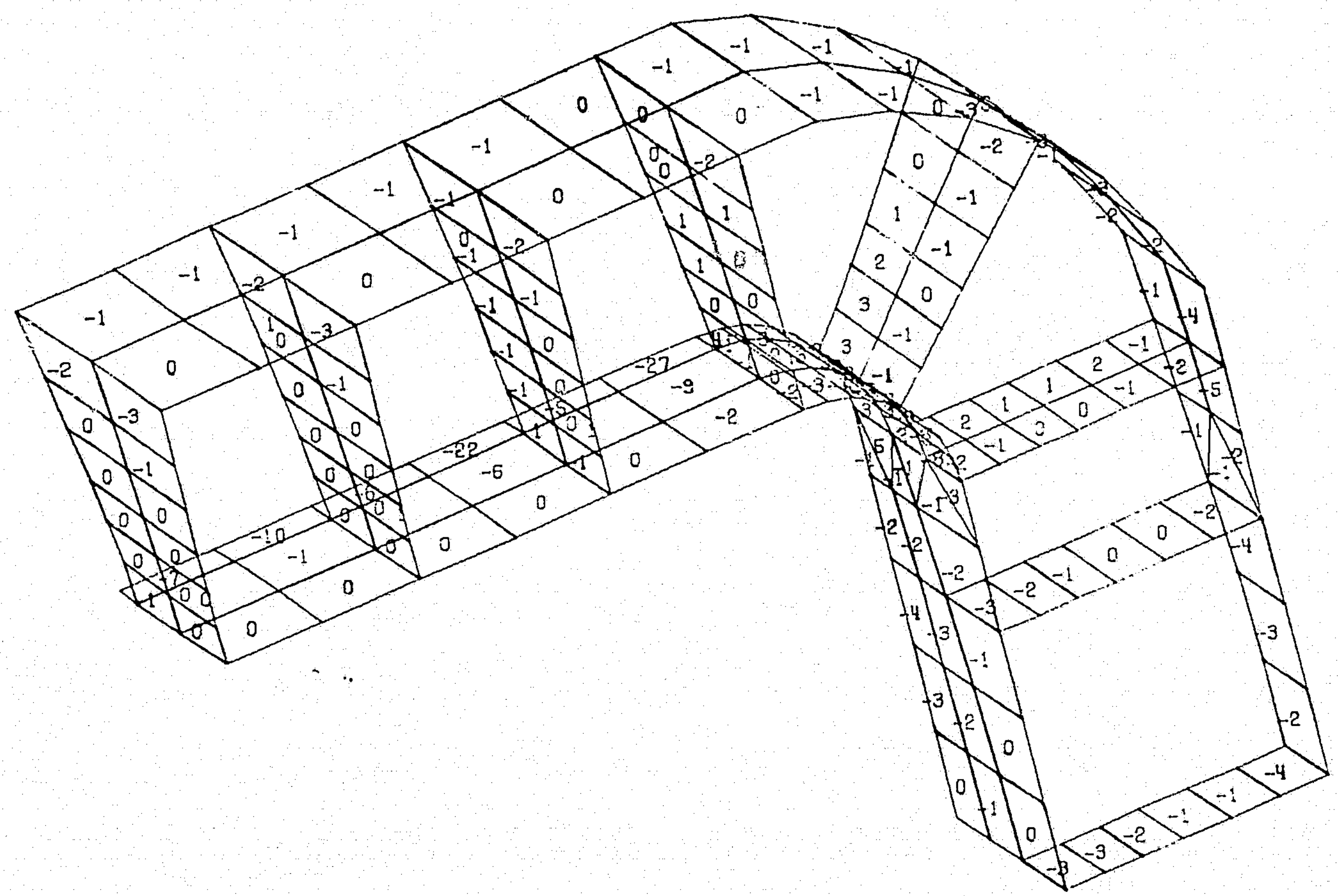
SPEC
5.1

NTF 9X12 ACESS OPENING
GUSSET

Figure 34

10/1/1

DISPLAY= PS2 /1000 , NODE= 1, SURFACE= 0



0 18
SCALE

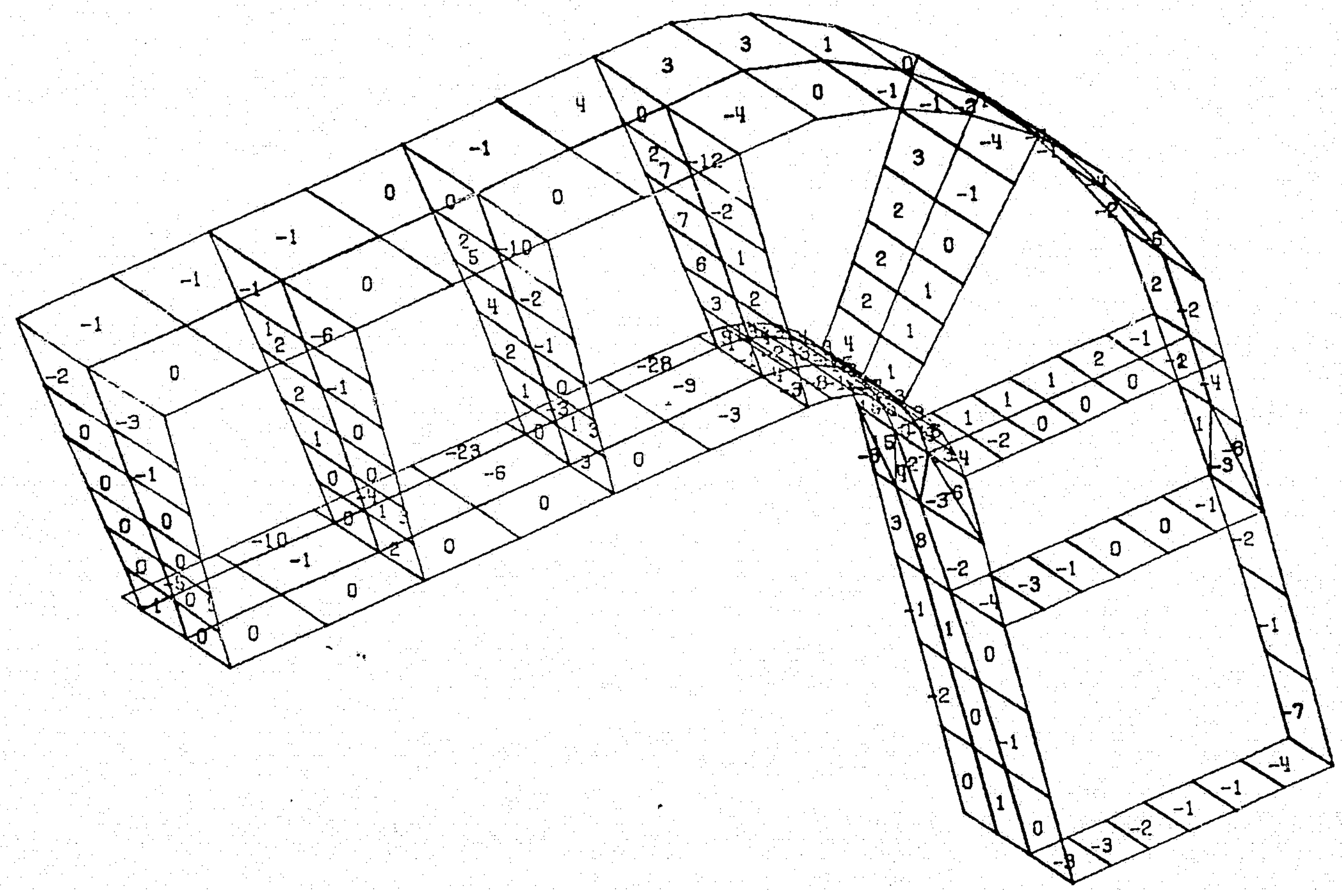
SPEC
5.1

NTF 9X12 ACESS OPENING
GUSSET

Figure 35

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1



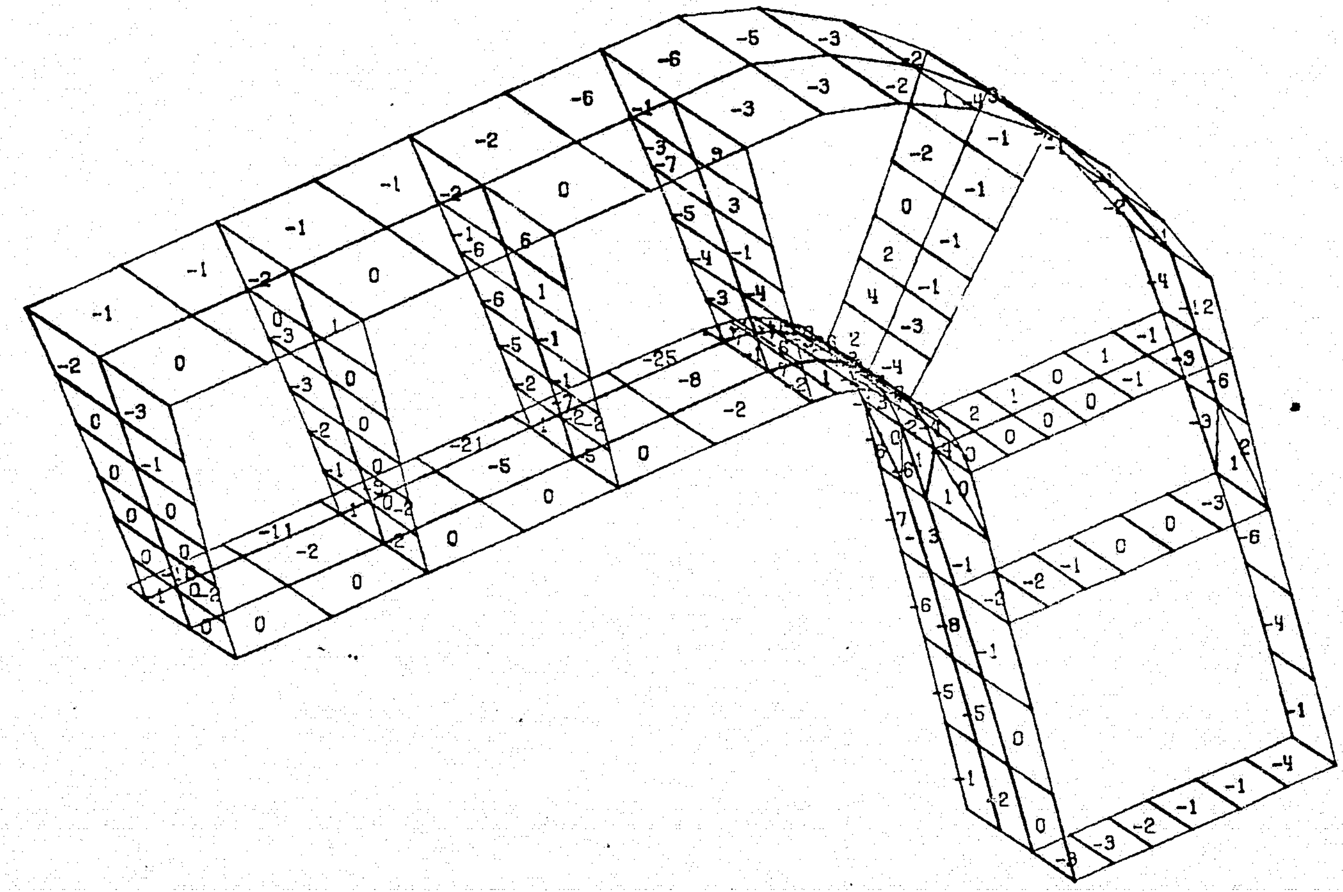
SPEC
5.1

NTF 9X12 ACESS OPENING
GUSSET

Figure 36

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2



0 18
SCALE

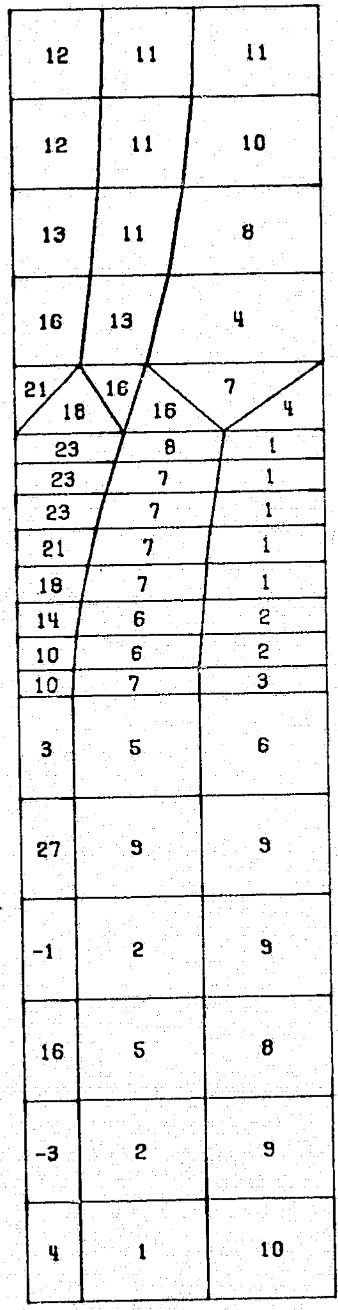
SPEC
5.1

NTF 9X12 ACESS OPENING
GUSSET

Figure 37

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



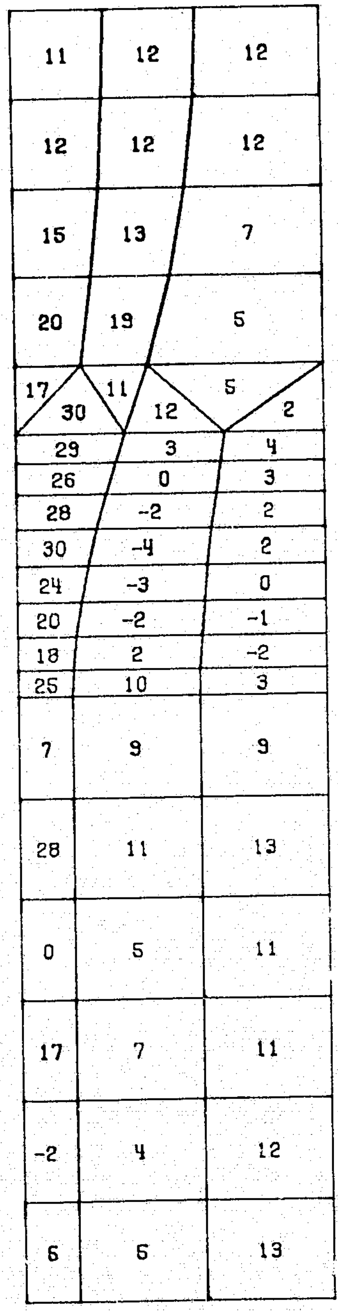
SPEC 6.1 NTF 9X12 REINF. INNER RING

0 SCALE 14

Figure 38

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



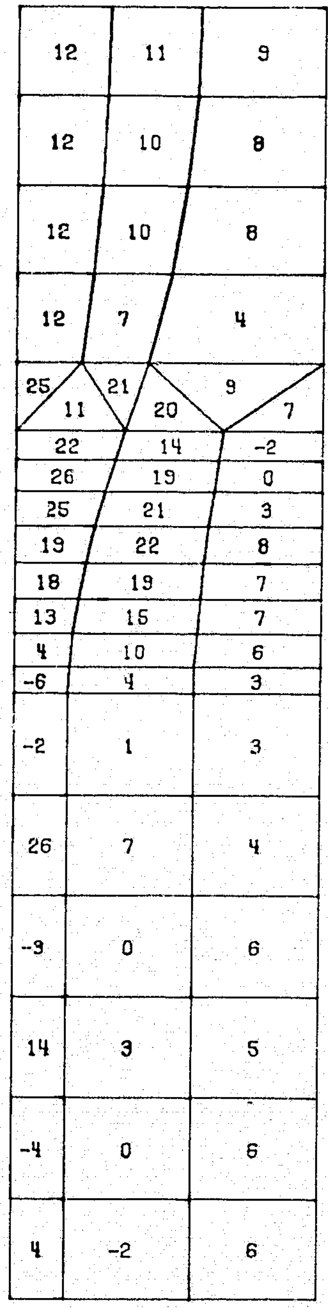
SPEC 6.1 NTF 9X12 REINF. INNER RING

0 14 SCALE

Figure 39

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2



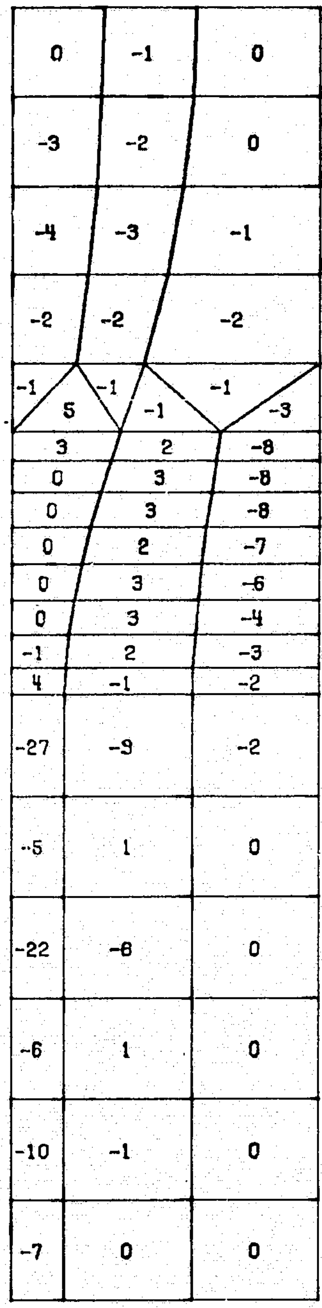
SPEC 6.1

NTF 9X12 REINF.
INNER RING

0 14
SCALE

Figure 40

DISPLAY= PS2 /1CCC , NODE= 1, SURFACE= 0



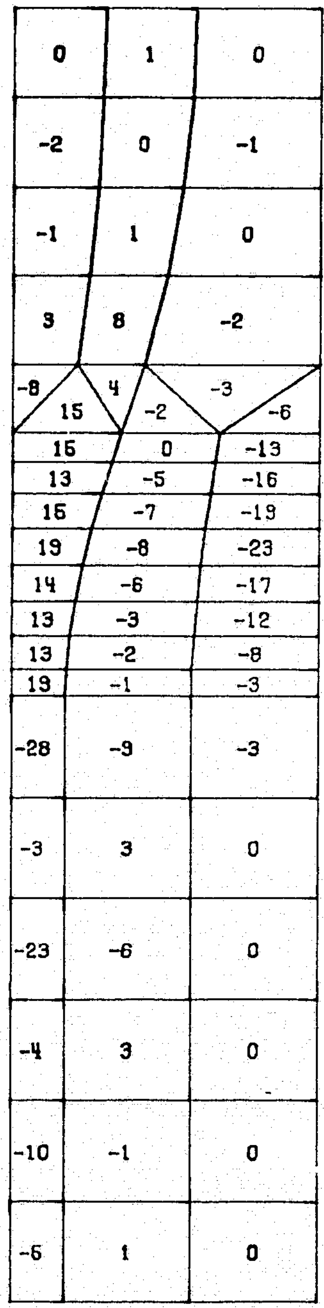
SPEC 6.1 NTF 9X12 REINF. INNER RING

0 14 SCALE

Figure 41

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1



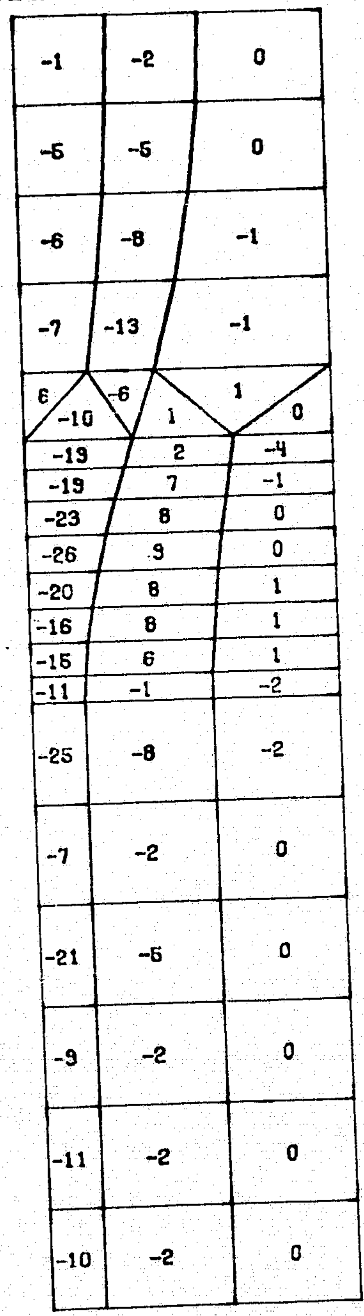
SPEC 6.1 NTF 9X12 REINF. INNER RING

0 14 SCALE

Figure 42

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2



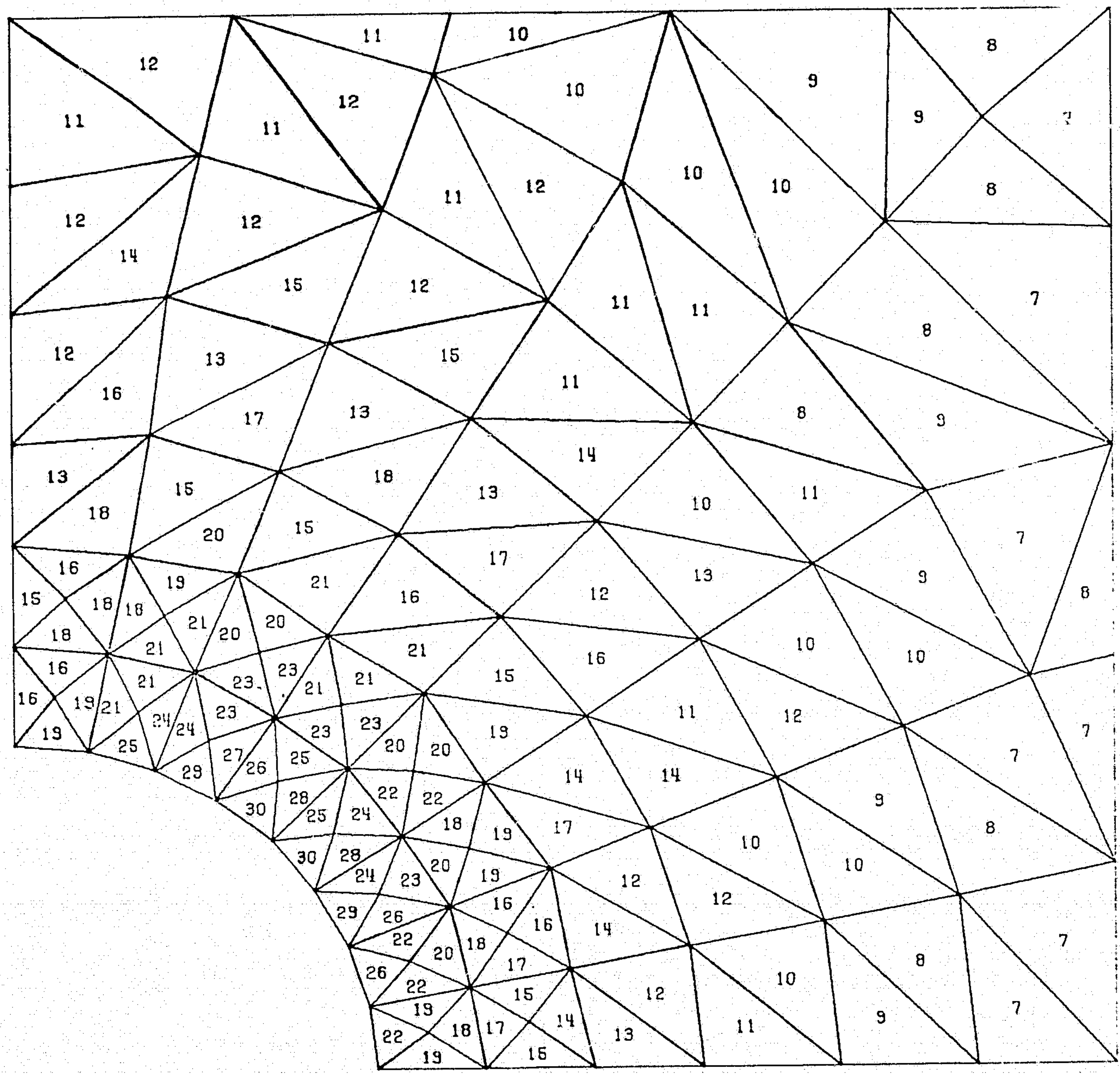
0 SCALE

SPEC 6.1 NTF 9X12 REINF. INNER RING

Figure 43

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



SPEC 8.1

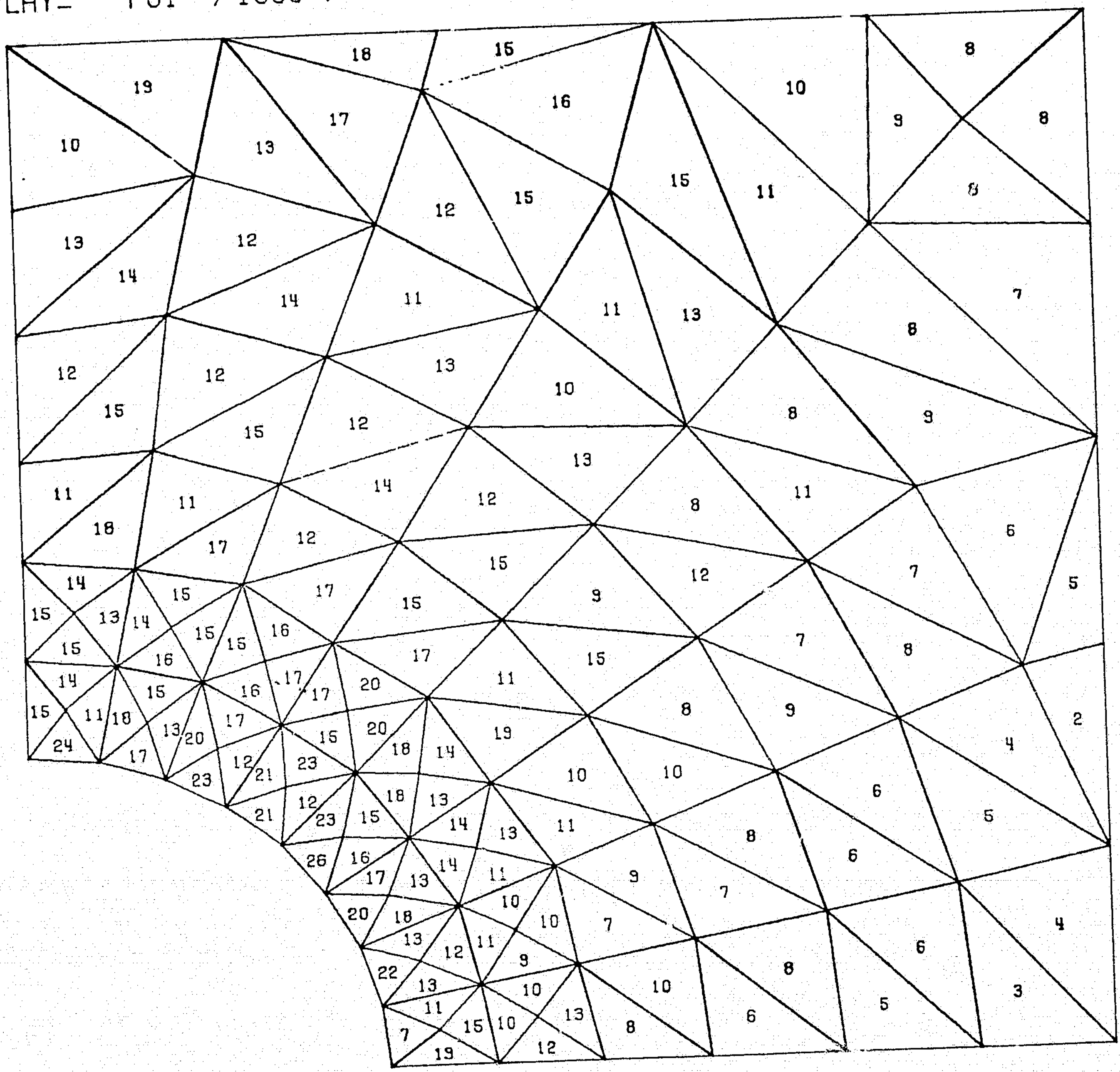
NTF 9 X 12 REINF
CENTER TRIANGLES

0 6
SCALE

Figure 44

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



0 6
SCALE

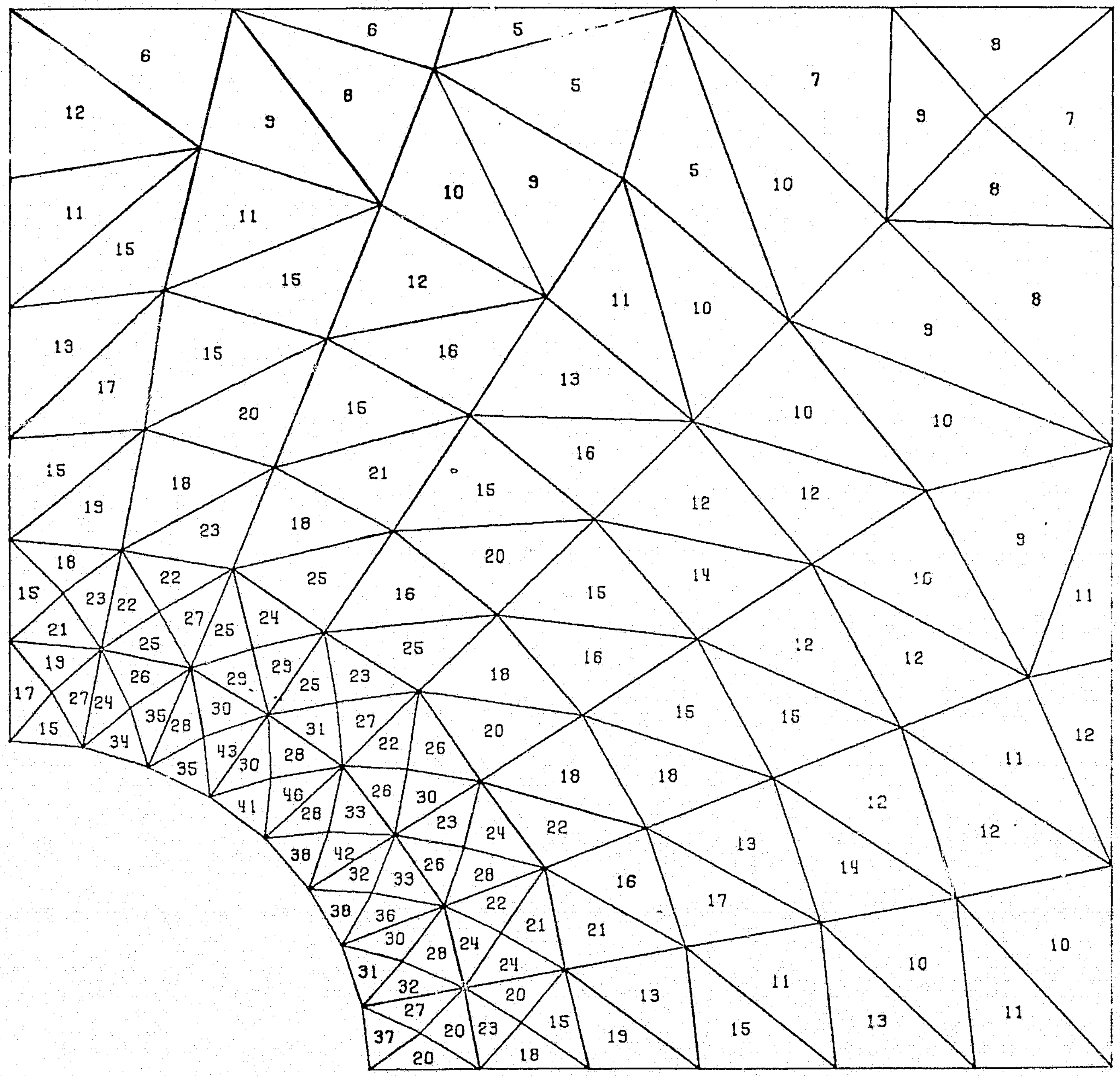
SPEC
8.1

NTF 9 X 12 REINF
CENTER TRIANGLES

Figure 45

10/1/1

DISPLAY= PS1 /10C0 , NODE= 1 , SURFACE= 2



SPEC
8.1

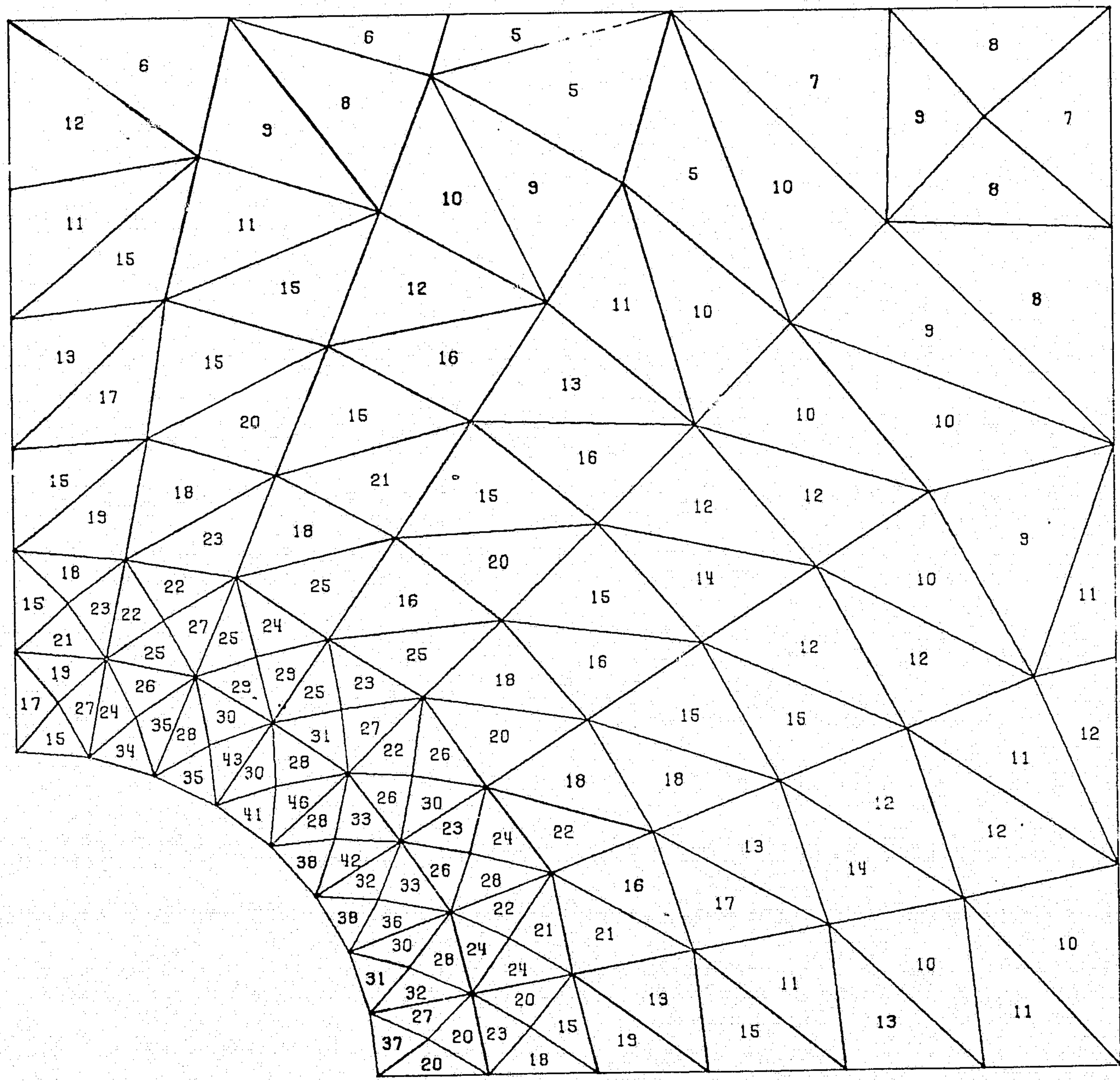
NTF 9 X 12 REINF
CENTER TRIANGLES

0 6
SCALE

Figure 46

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2



SPEC
8.1

NTF 9 X 12 REINF
CENTER TRIANGLES

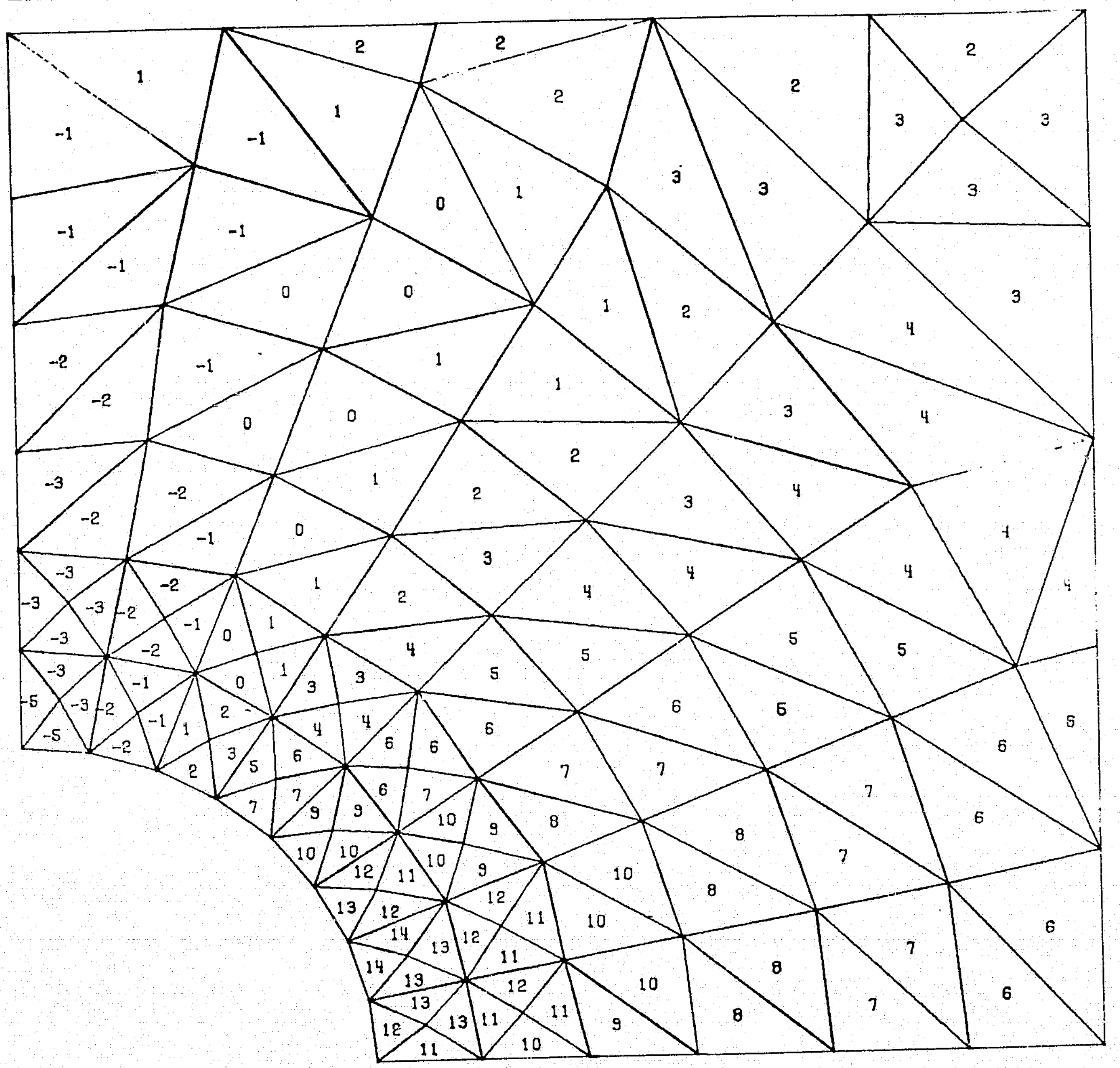
0 SCALE 6

Figure 46

2

10/1/1

DISPLAY= PS2 /1000, NODE= 1, SURFACE= 0



0 SCALE 6

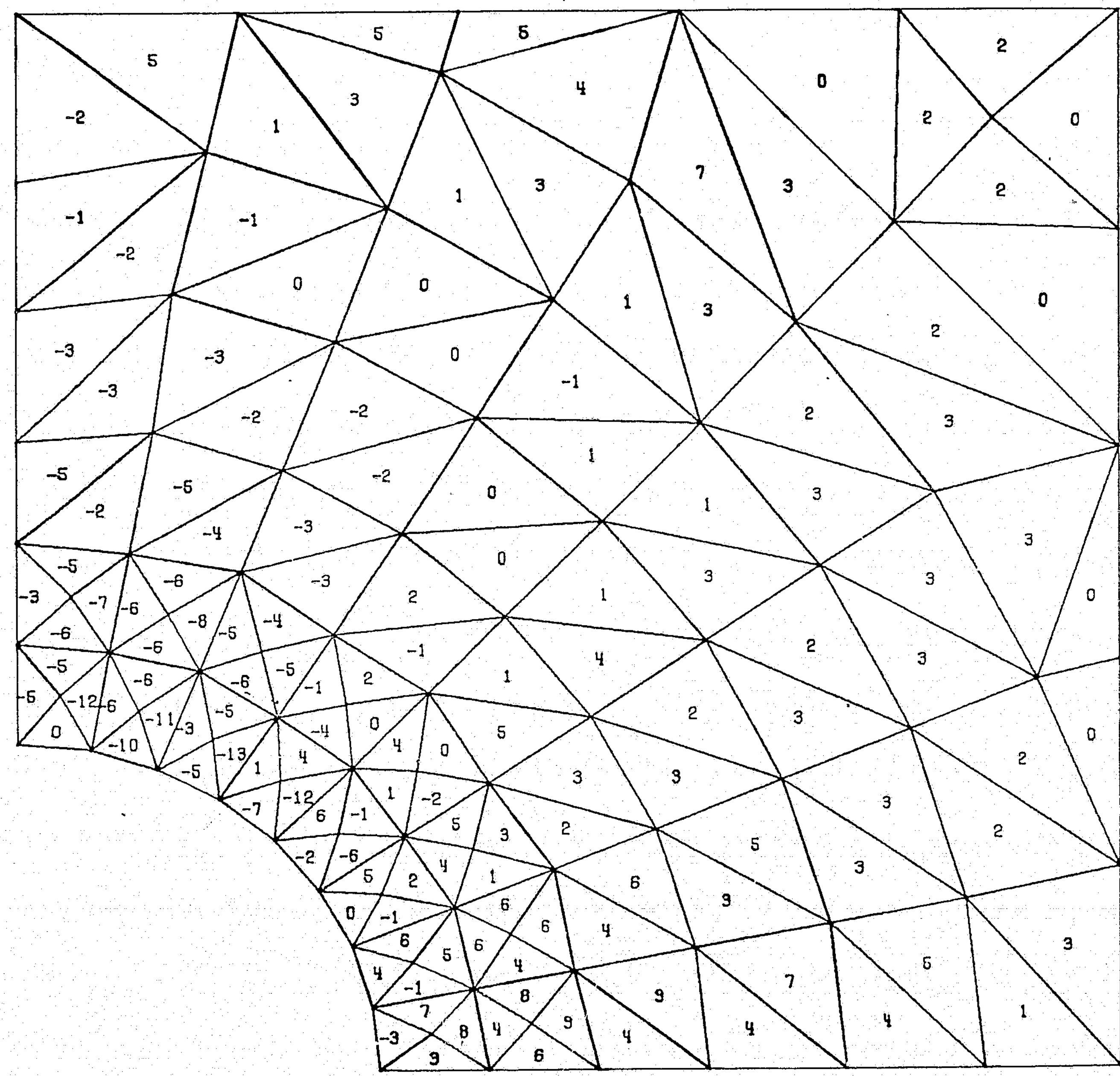
SPEC
8.1

NTF 9 X 12 REINF
CENTER TRIANGLES

Figure 47

10/1/1

DISPLAY= PS2 /1000 , NODE= 1, SURFACE= 1



SPEC 8.1

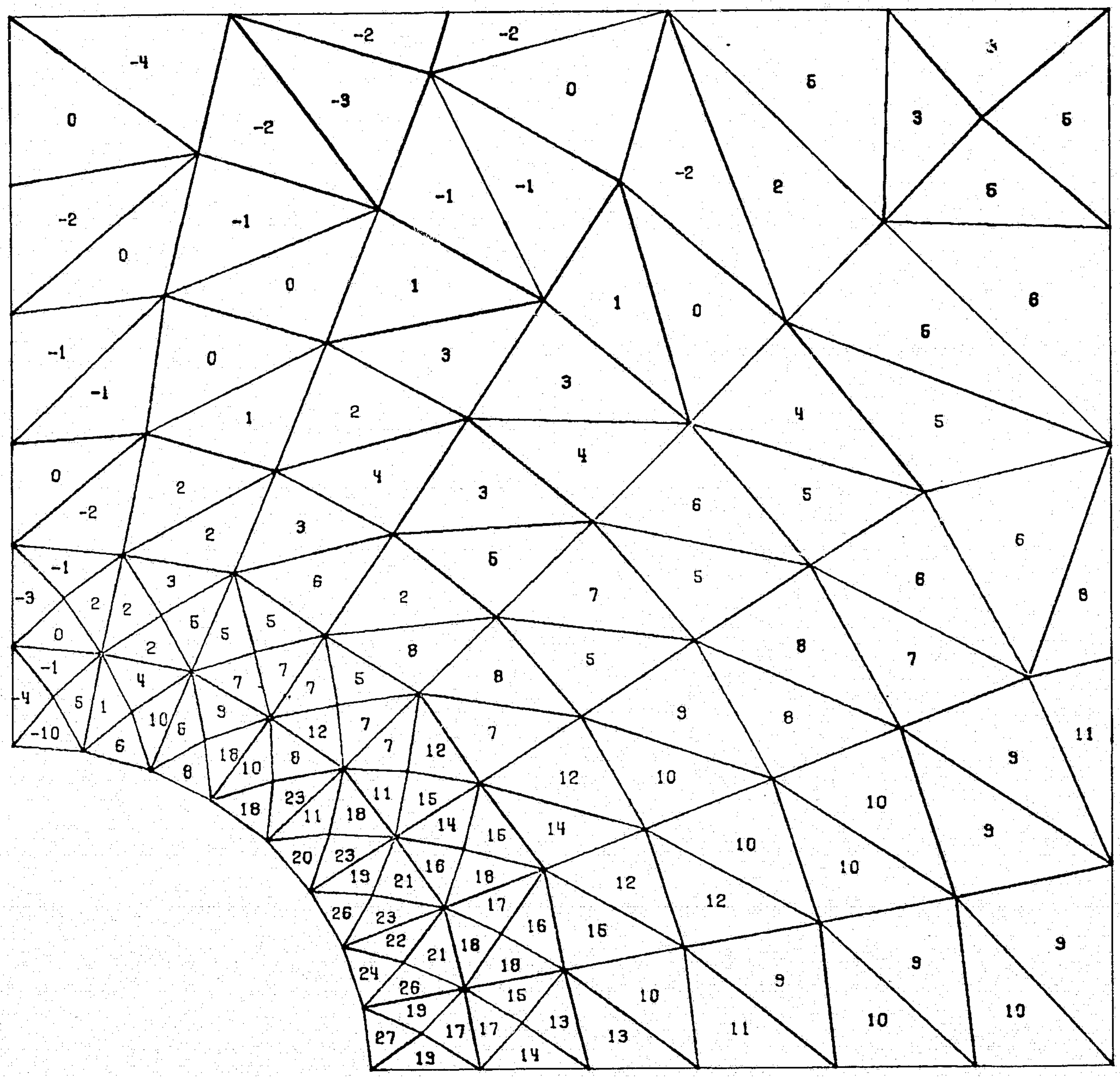
NTF 9 X 12 REINF
CENTER TRIANGLES

0 6
SCALE

Figure 48

10/1/1

DISPLAY= PS2 /1000 , NODE= 1, SURFACE= 2



SPEC
8.1

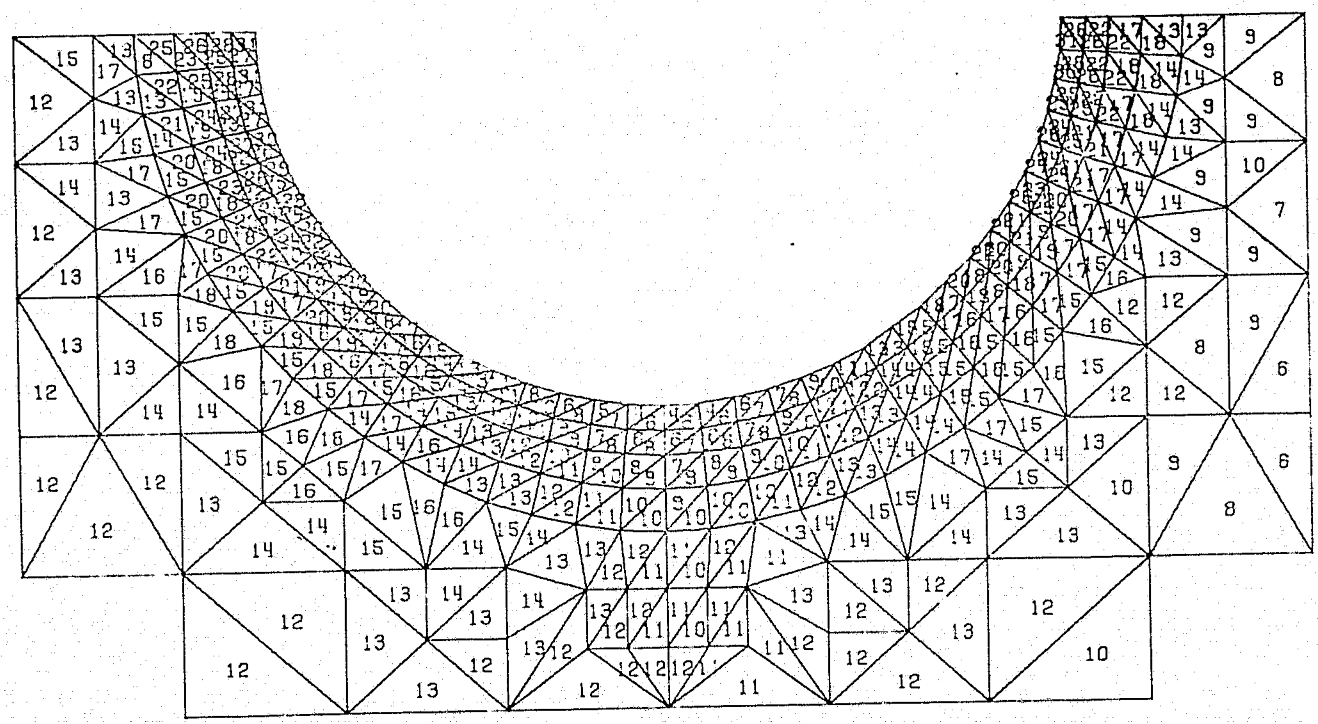
NTF 9 X 12 REINF
CENTER TRIANGLES

0 6
SCALE

Figure 49

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



SPEC 9.1

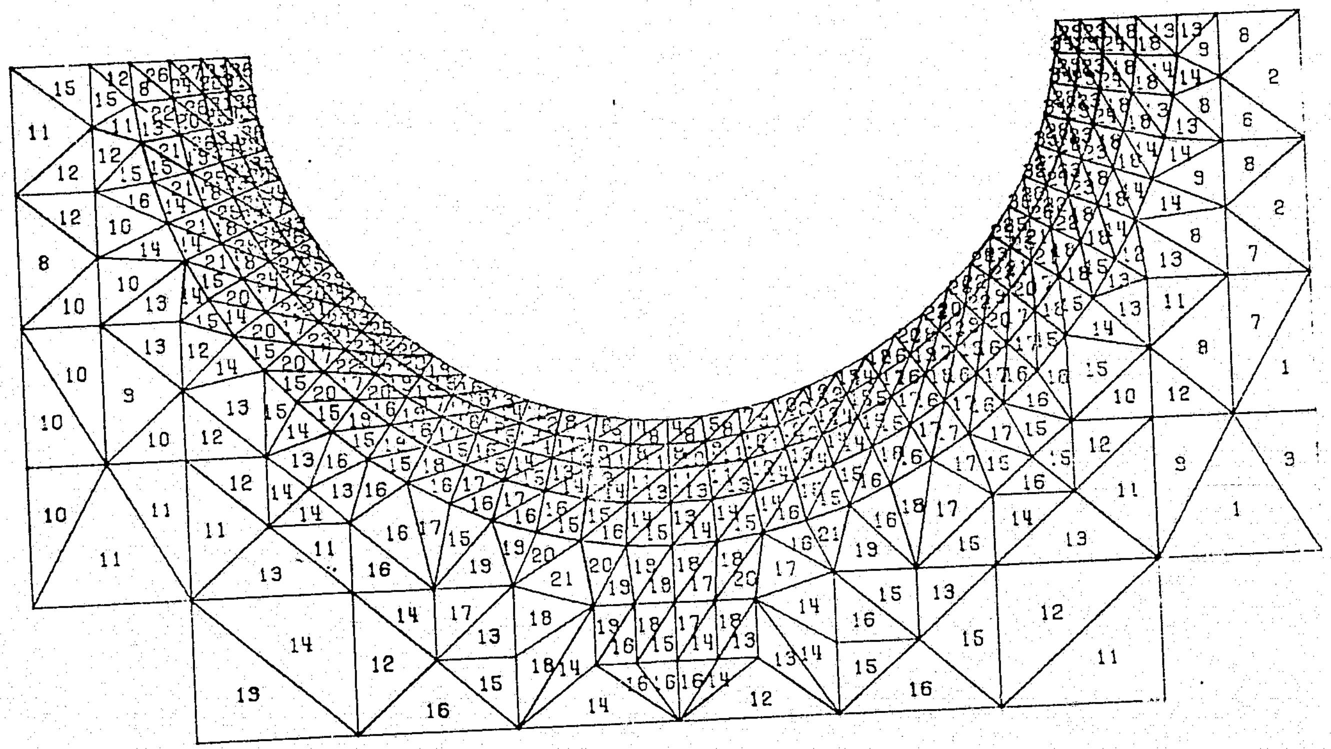
9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

0 24
SCALE

Figure 50

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



0 24
SCALE

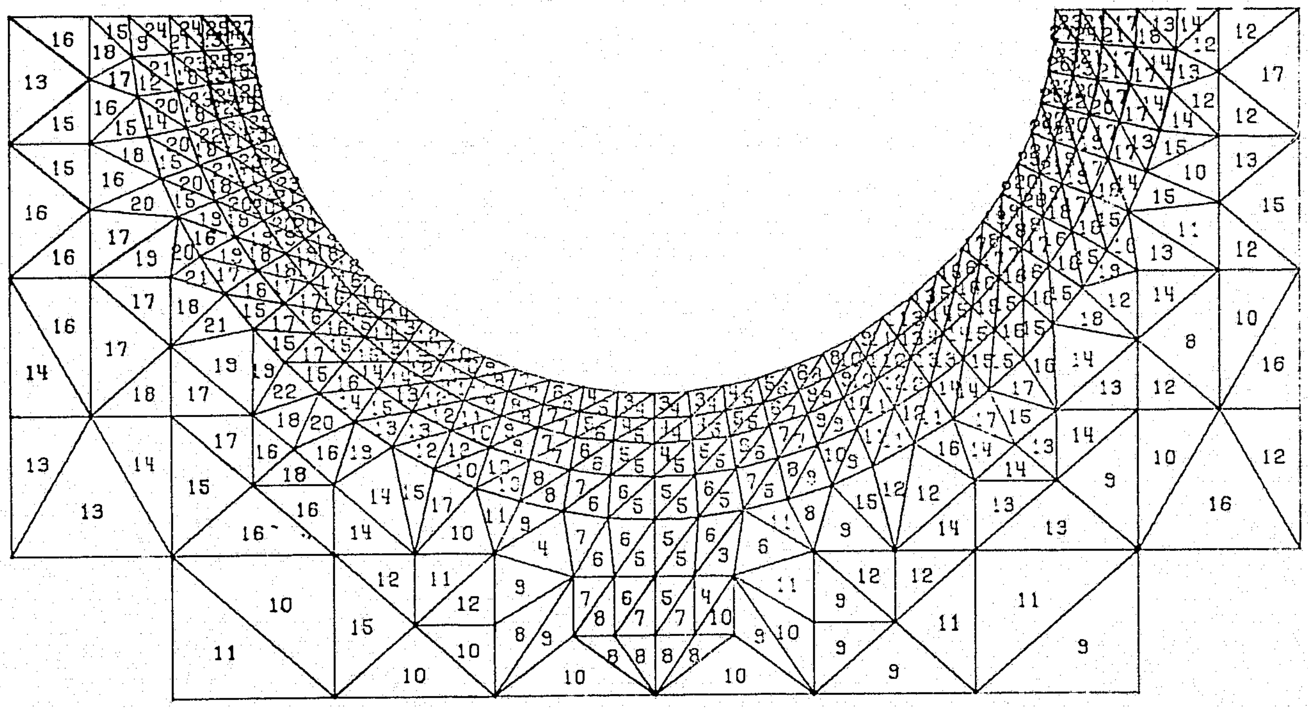
SPEC 9.1

9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

Figure 51

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2



SPEC
9.1

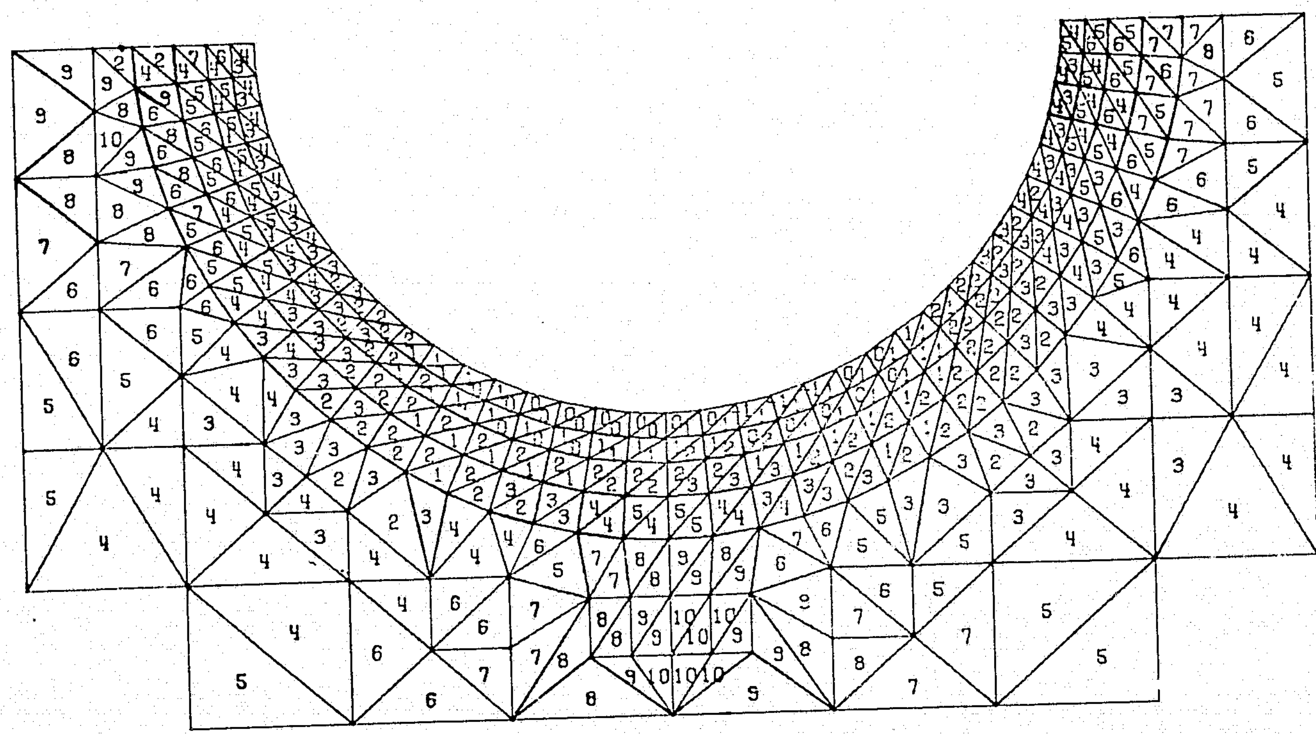
9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

0 24
SCALE

Figure 52

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0



SPEC 9.1

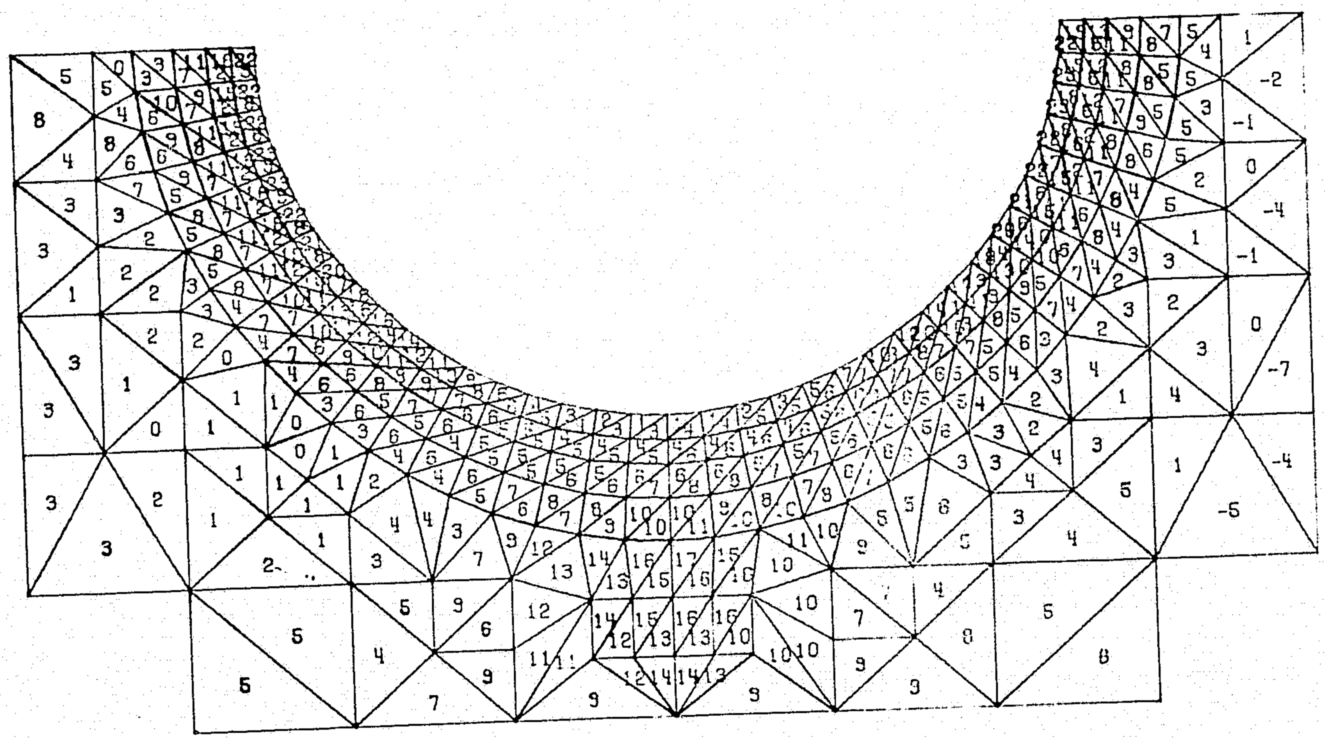
9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

0 24 SCALE

Figure 53

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1



0 24
SCALE

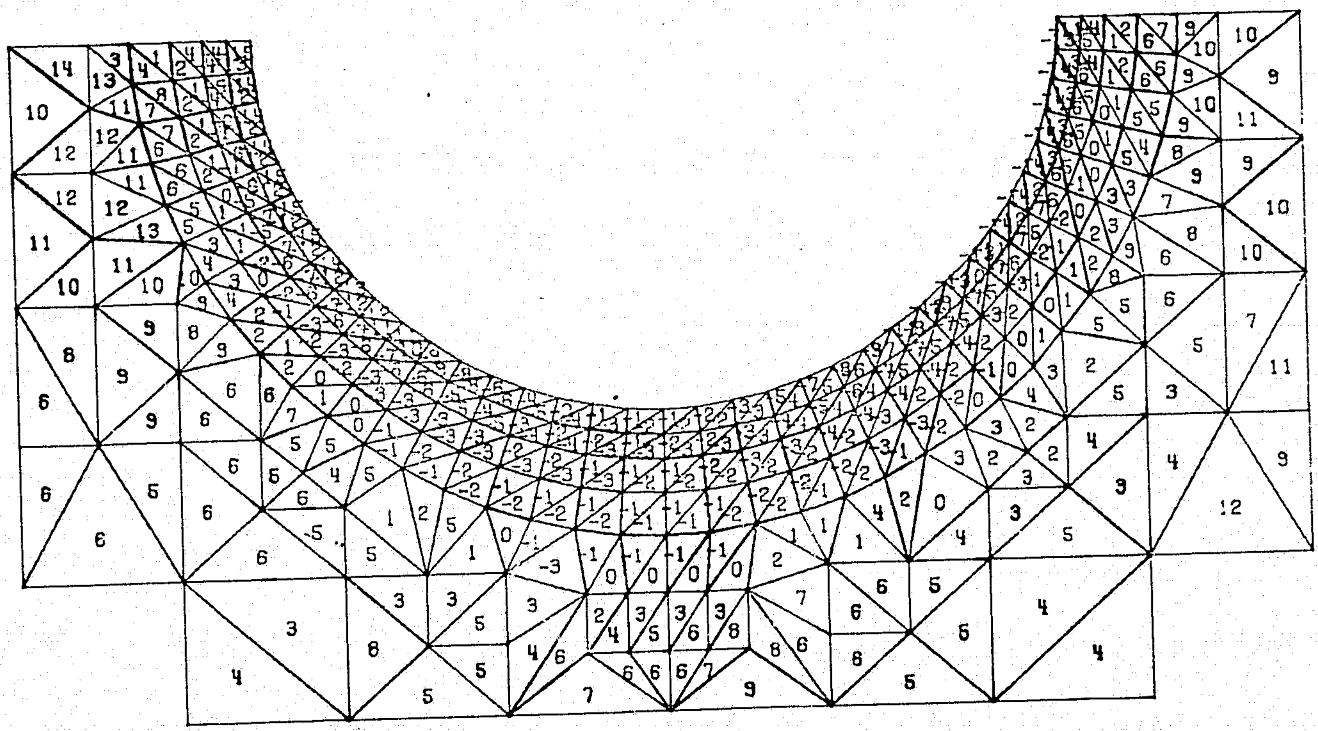
SPEC 9.1

9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

Figure 54

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2



0 24
SCALE

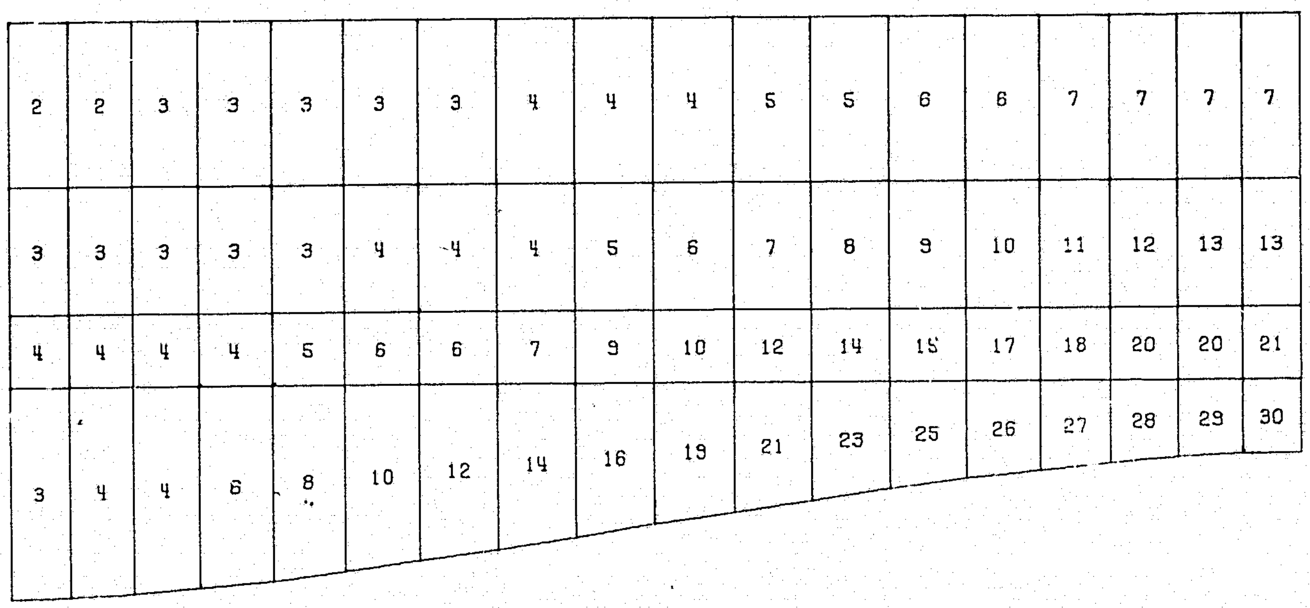
SPEC 9.1

9 X 12 REINF WITH 9 FT HOLE
TRIANGLES AROUND 9 FT HOLE

Figure 55

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 0



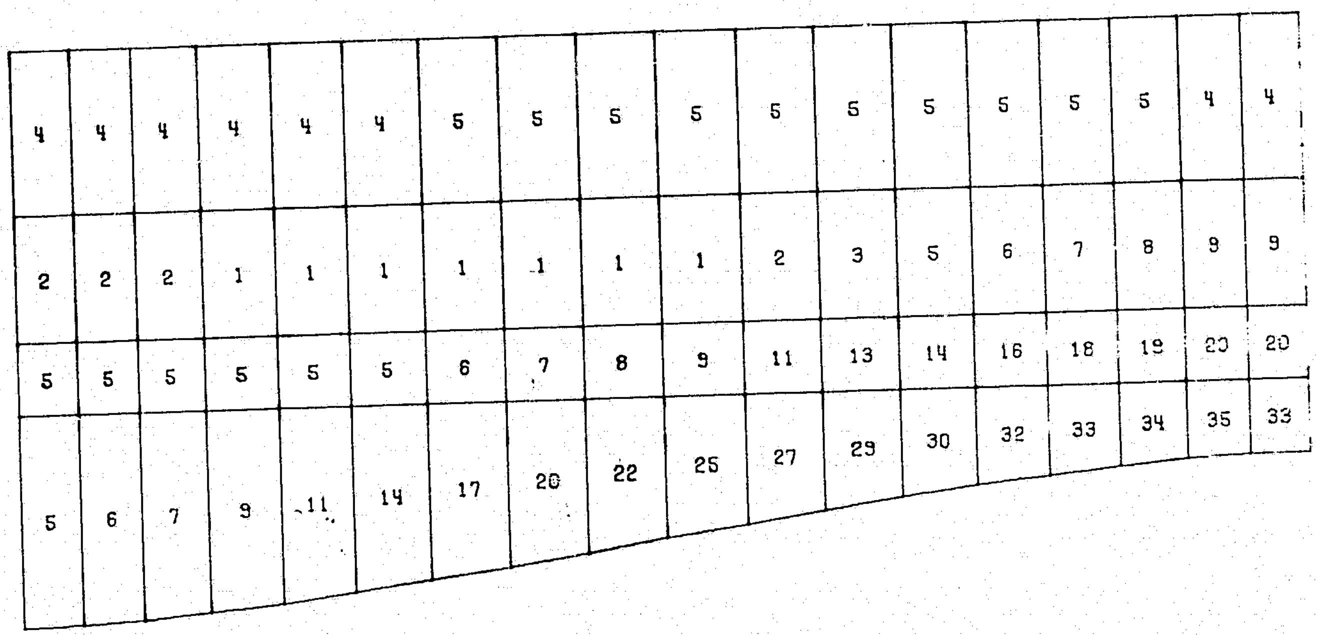
SPEC 10.1 — 9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 — 11
SCALE

Figure 56

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



SPEC 10.1

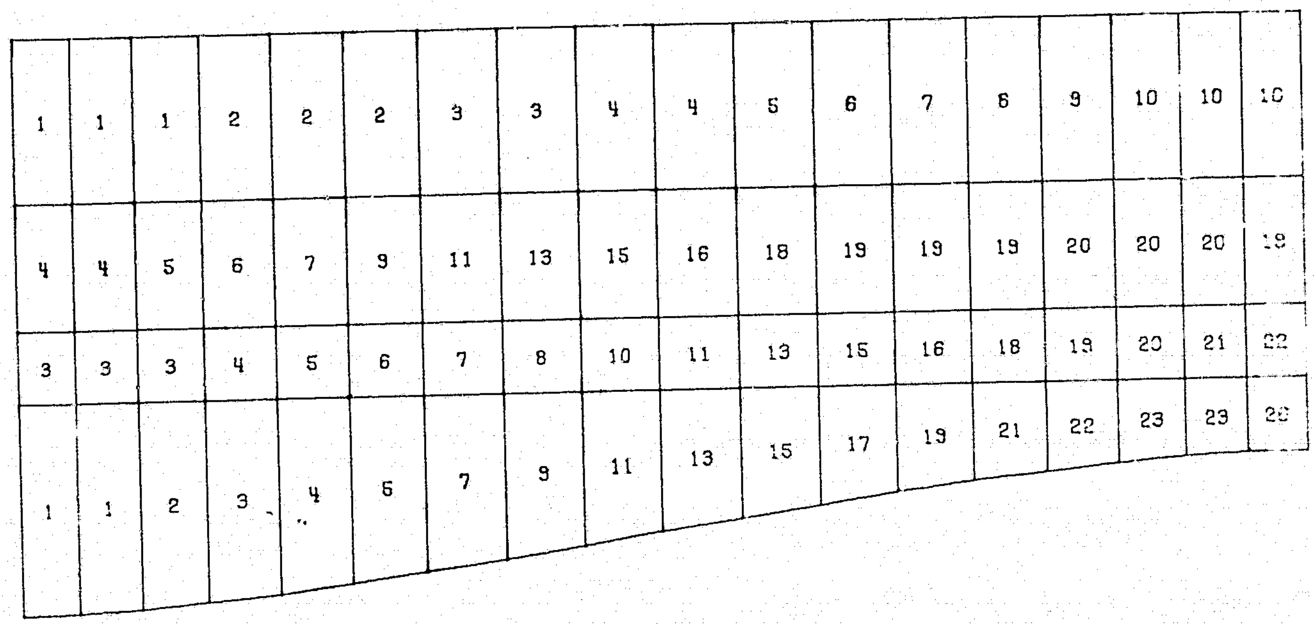
9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 SCALE 11

Figure 57

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2



SPEC 10.1

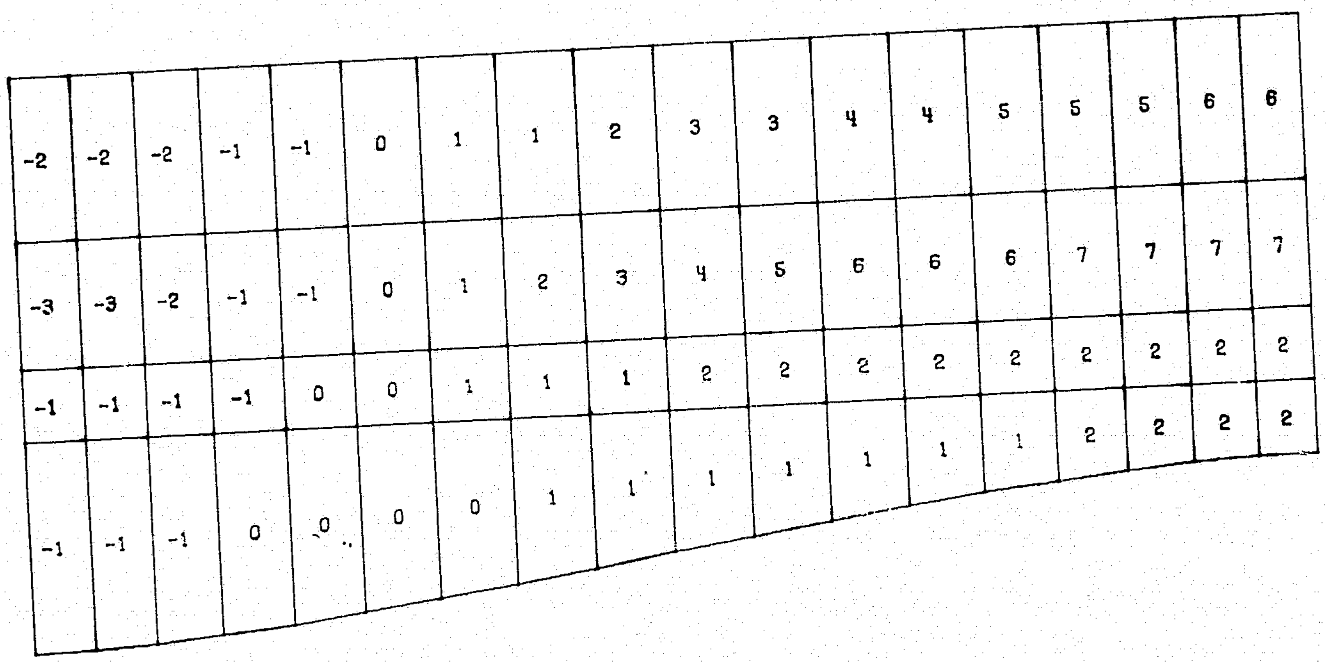
9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 11
SCALE

Figure 58

10/1/1

DISPLAY= PS2 /1COC , NCDE= 1 , SURFACE= 0



0 11
SCALE

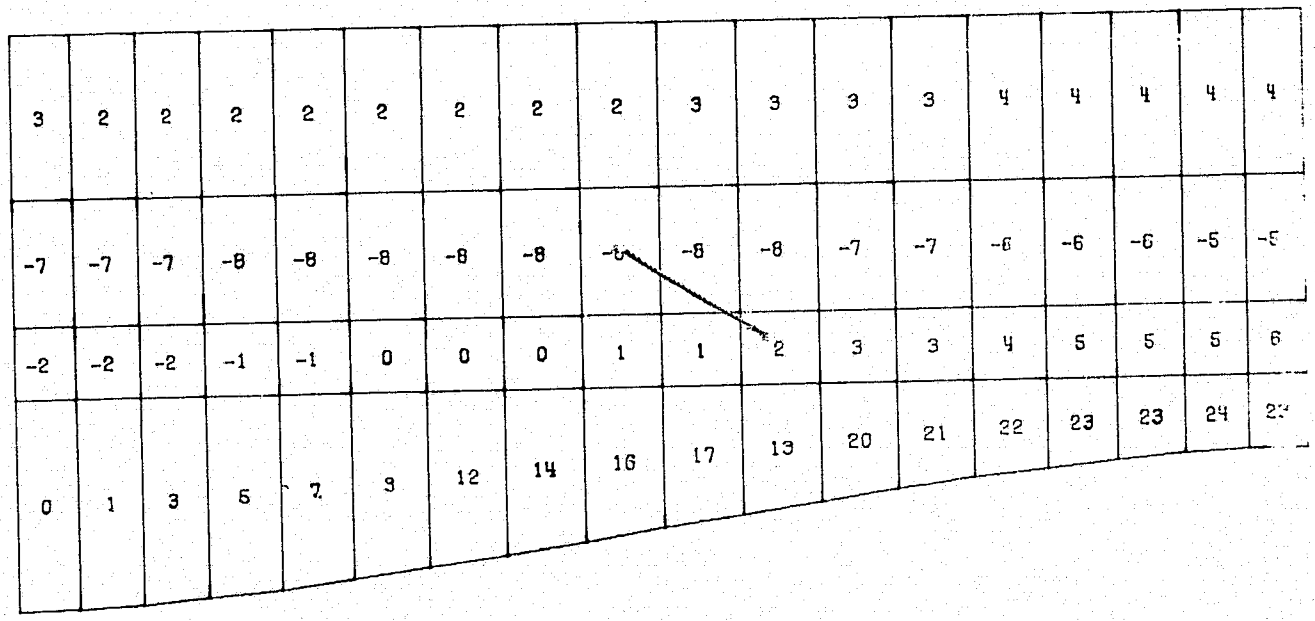
SPEC 10.1

9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

Figure 59

10/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1



SPEC 10.1

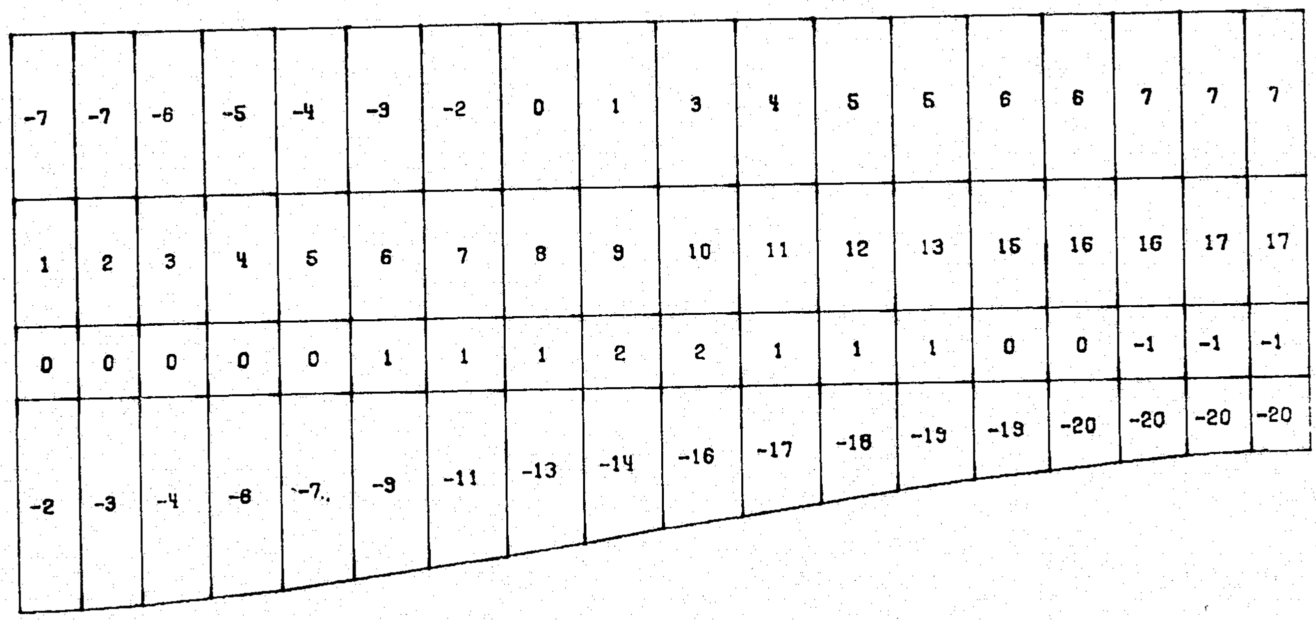
9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 SCALE

Figure 60

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2



SPEC 10.1

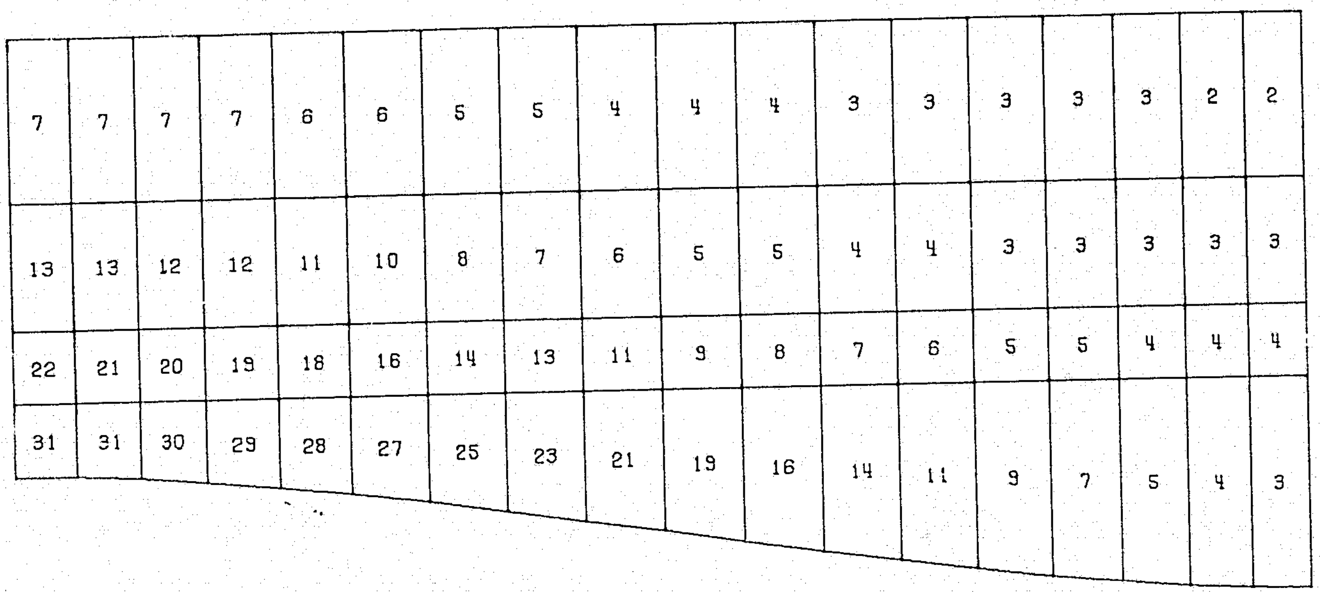
9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 1

0 11 SCALE

Figure 61

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



SPEC 11.1

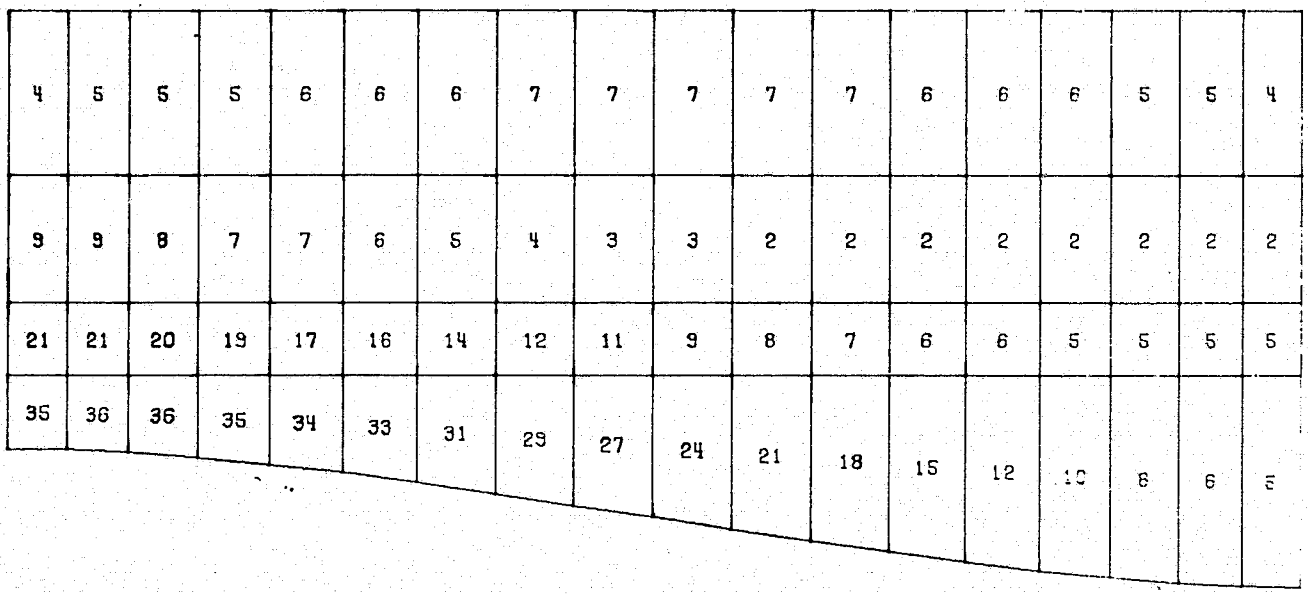
9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

0 1 SCALE

Figure #2

DISPLAY= PS1 /10CC , NODE= 1, SURFACE= 1

10/1/1



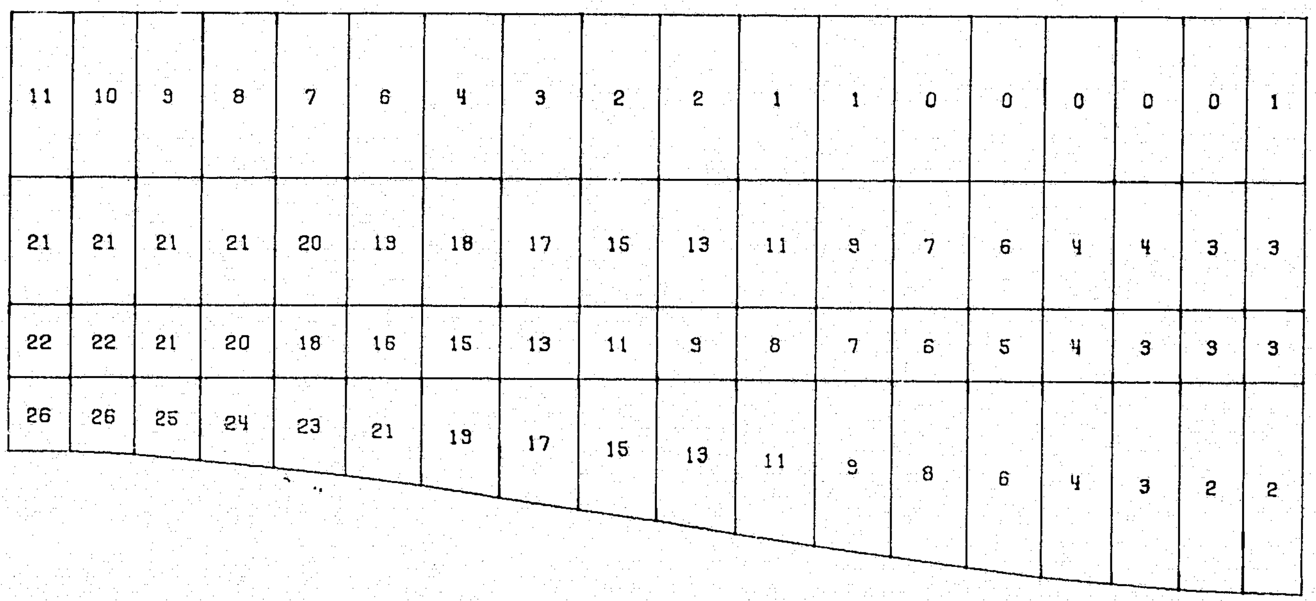
SPEC 11.1

9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

0 1
SCALE

Figure 63

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2 10/1/1



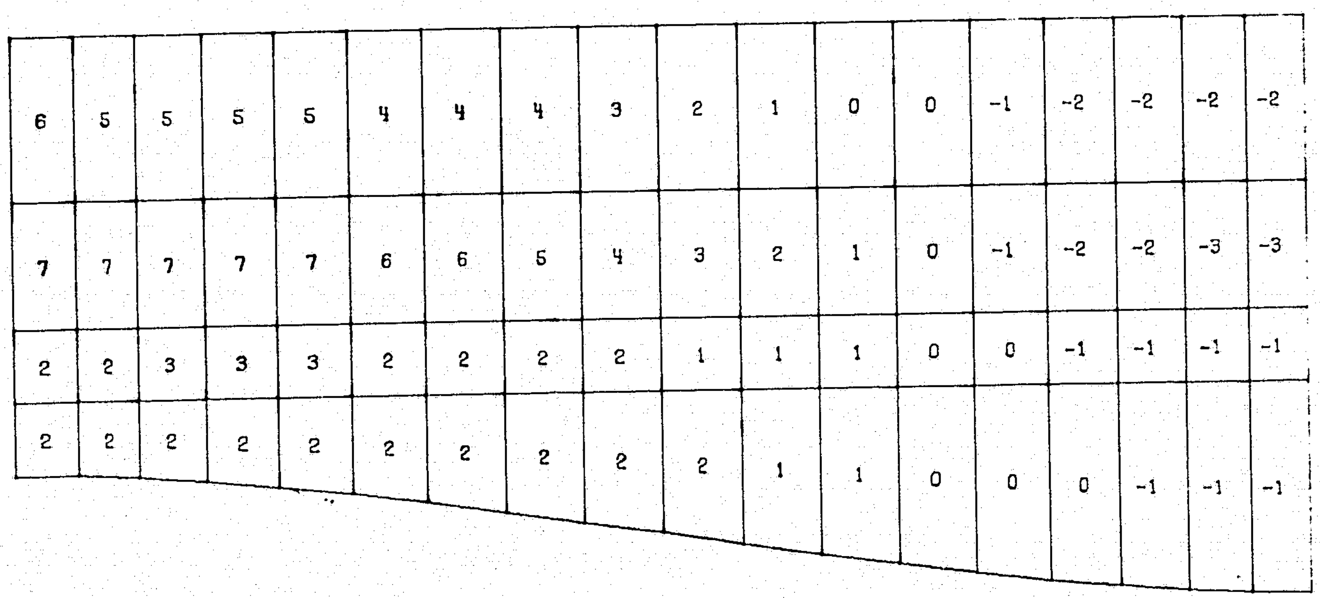
SPEC 11.1 9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

0 11 SCALE

Figure 64

10/1/1

DISPLAY= PS2 /1000 , NODE= 1, SURFACE= 0



SPEC 11.1 9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

0 SCALE 1

Figure 65

10/1/1

DISPLAY= PS2 /100C , NODE= 1 , SURFACE= 1

4	4	4	4	4	5	5	5	6	6	4	4	4	4	4	3	3	3
-7	-7	-7	-6	-6	-6	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
5	5	5	4	3	2	1	0	-1	-1	-2	-3	-3	-3	-3	-3	-3	-3
23	23	23	23	23	22	21	20	18	16	13	11	8	5	3	2	0	0

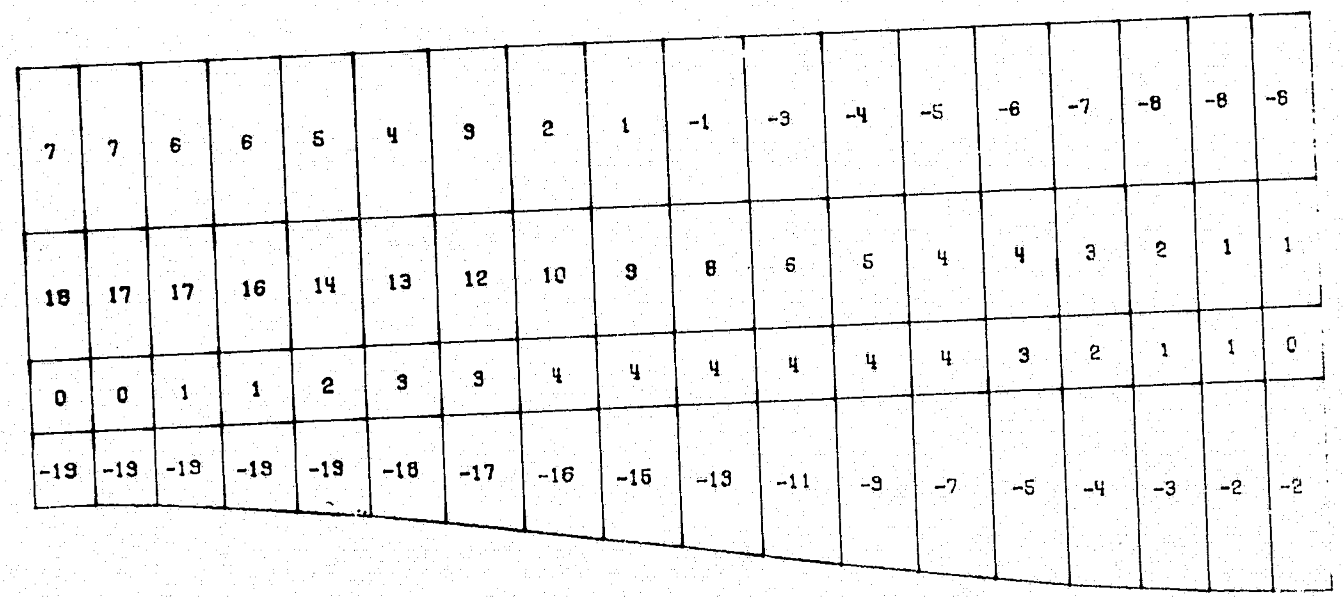
SPEC 9 X 12 REINF WITH 9 FT HOLE
11.1 9 FT PIPE SECTION 2

0 SCALE 11

Figure 66

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

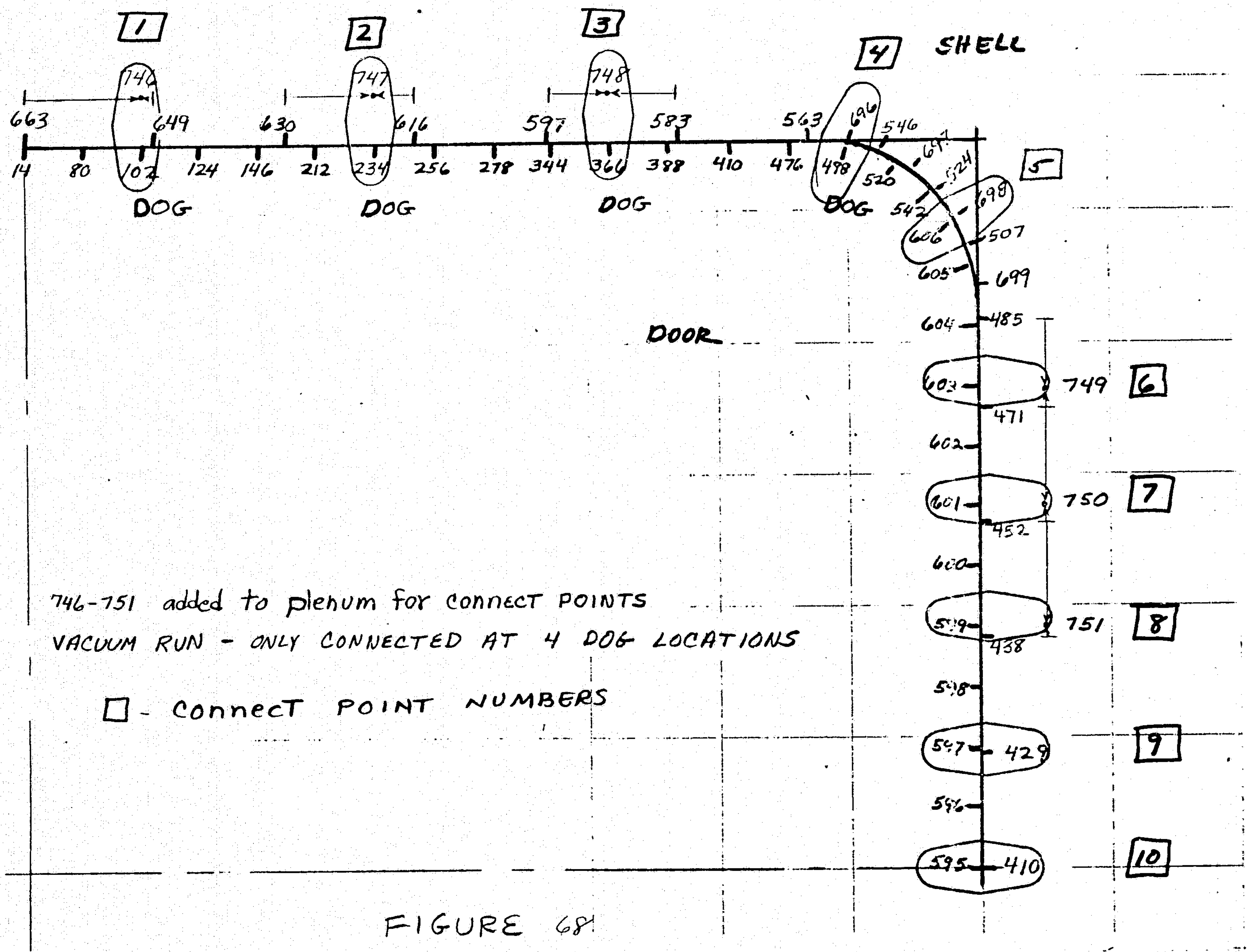


0 11
SCALE

SPEC 11.1

9 X 12 REINF WITH 9 FT HOLE
9 FT PIPE SECTION 2

Figure 67



746-751 added to plenum for connect points

VACUUM RUN - ONLY CONNECTED AT 4 DOG LOCATIONS

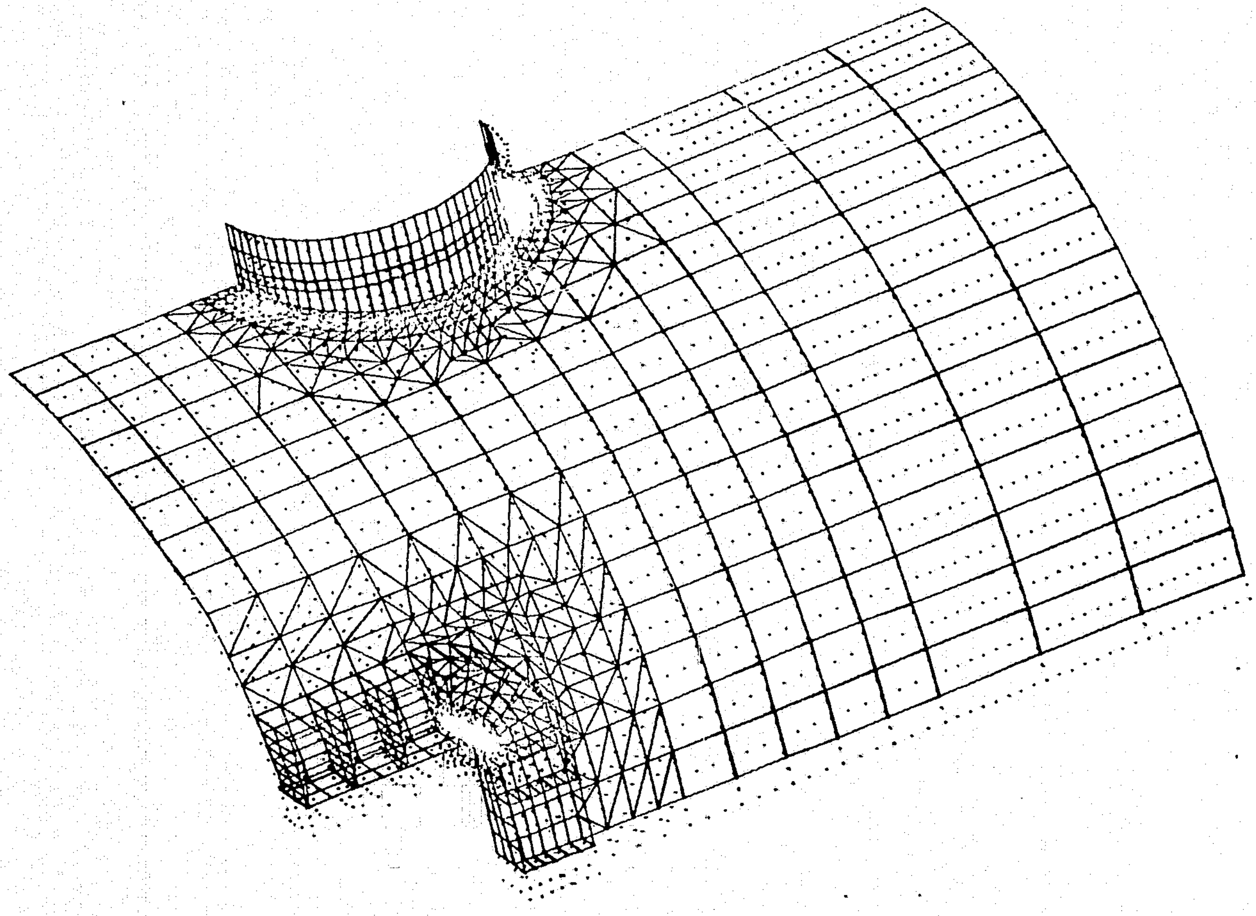
☐ - CONNECT POINT NUMBERS

FIGURE 68

JOB NO 7-19-76

CHKD. BY______ DATE______

BUCKLING MODE, CRITICAL LOAD .119957 X10 +02 1/7/1



SPEC 1.1 NTF 9 X 12 ACCESS OPENING *Fig 69*

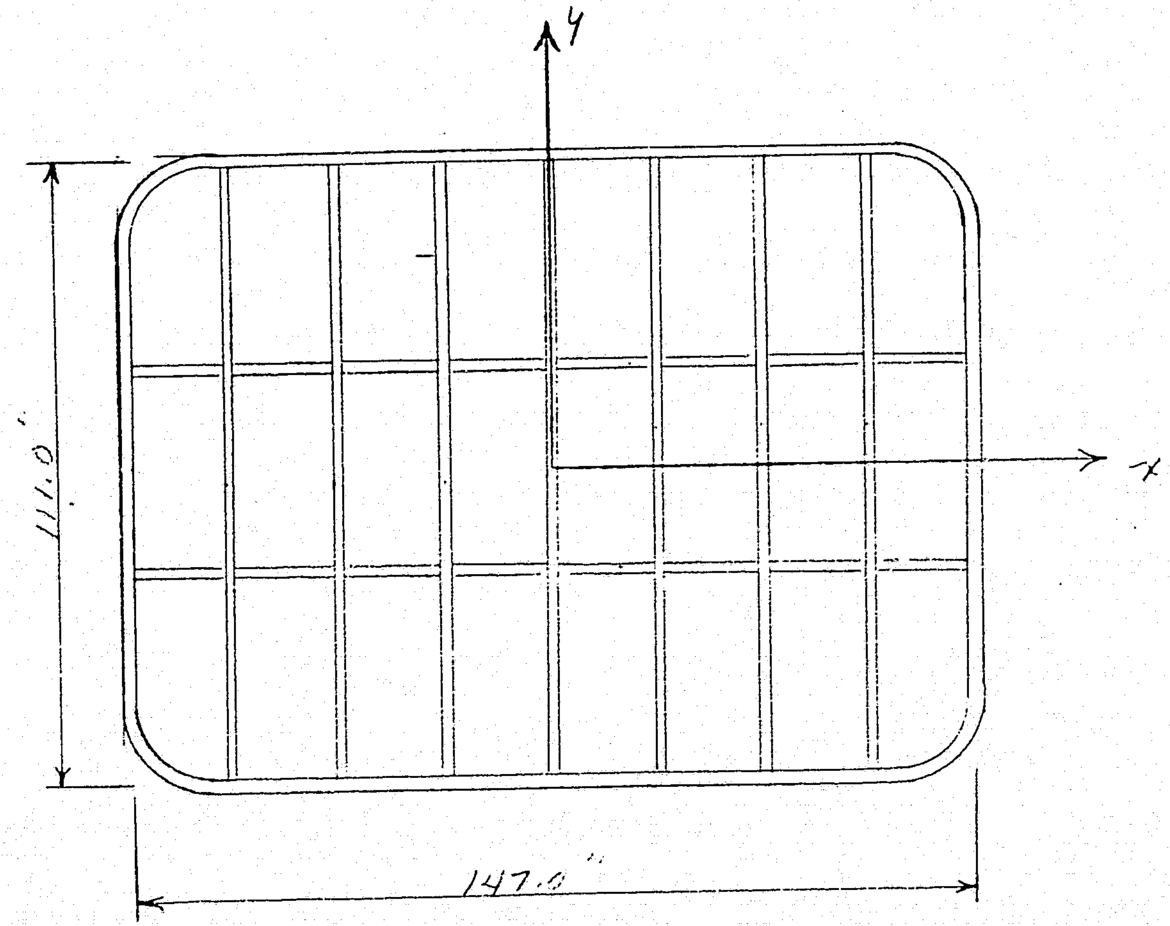
BY __________ DATE __________
CHKD. BY __________ DATE __________

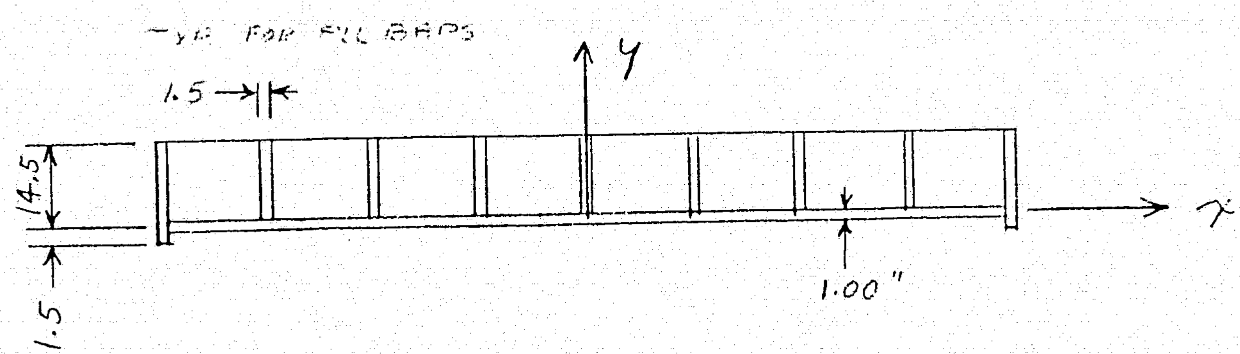
SUBJECT NTF
Finite Element Analyses of
Side Access Door

SHEET NO. 1 OF ______
JOB NO. __________

Reference Drawing LE944471

9% Ni





BY ______ DATE ______ SUBJECT ______ SHEET NO. 2 OF ______
CHKD. BY ______ DATE ______ JOB NO. ______

SPAR (a finite element computer code developed + maintained by Engineering Information System, Inc. under NASA contract NAS8-30536 and NAS1-13977) was used to analyse this region of the pressure shell. The region was modeled using triangular and quadrilateral, membrane plus bending flat aeolotropic elements

The final configuration shown on LE 944471 is slightly different from the configuration modeled. The plate is now the sealing surface with all the stiffner right above the plate (Total hight plate + stiffener = 17") rather that a 1.5" high stiffner for the sealing surface and 14.5" high stiffeners on opposite side of the plate.

BY ______ DATE: ______ SUBJECT ______ SHEET NO. 3 OF ______
CHKD. BY ______ DATE ______ JOB NO. ______

The total height (sealing stiffner + plate + stiffner) is 17.0".

It was judged that these discrepancies would have min. effect on the Door / Plenum results.

One-quarter of the door was modeled. The horizontal and vertical ℄ of the door were planes of symmetry.

A computer plot of the door is show in Fig 1 A. The model consist of 606 joint with 6 DOF at each joint except where boundary condition were applied and rotation about an axis ⊥ to a plate element was restricted as required

BY ____ DATE ____ SUBJECT ____ SHEET NO. 4 OF ____
CHKD. BY ____ DATE ____ JOB NO. ____

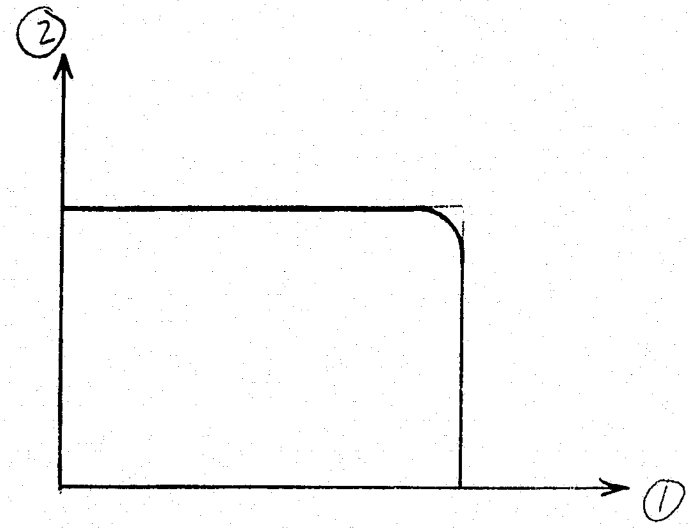
The joint numbers and shell section properties are shown in Fig 2 thru 11

The section properties and thicknesses are listed below

Shell Section Property	Thickness
1	1.0
2	1.5
3	1.5
4	1.5
5	0.75
6	1.50
7	1.50

BY ______ DATE ______ SUBJECT ______ SHEET NO. 5 OF ______
CHKD. BY ______ DATE ______ JOB NO. ______

Boundary Condition



Plane 1 3 is plane of symmetry

Plane 2 3 is plane of symmetry

Force displacements (IN the 3 direction) obtained from combining the Door & Plenum models were applied to the edge of the Door

see discussion on combined analyses (p. 9 Plenum Analyses)

Loading

P= 119 psi (design pressure) was applied as nodal pressure to the joints of the pressure surface.

For vacuum condition, -15 psi was applied as nodal pressure to the joints of the pressure surface.

Combined Door + Plenum Analyses

See discussion in Finite Element Analyses of Access Door Reinforcement (Plenum (p. 9 Vol. 3 Part 1)

Results

Nodal stresses are presented in Fig 12 thru 69.

The max principal stress (PS1) or min. principal stress (PS2) are given for the mid-surface (surface 0), the stiffner bar side of the plate (surface 1), and the sealing surface side of the plate (surface 2).

The stresses plotted are for joint 1 of the element. As an example (reference Fig 2), for the element defined by joint 1, 67, 66, 2 joint 1 for that element is 1

Nodal stresses for one joint are given from 4 elements (for quadrilateral elements). If any discrepancies exist in the stresses for a joint, the larger value is used in the evaluation of the results.

BY ______ DATE ______ SUBJECT ______ SHEET NO. 8 OF ______

CHKD. BY ______ DATE ______ JOB NO. ______

[illegible] Stresses in Plate ($P = 119$ psig)

Max. at joint 1 (Fig 12)

$$\sigma_1 = 13.47 \text{ KSI}$$

$$\sigma_2 = 1.15 \text{ KSI}$$

$$\sigma_3 = -\frac{.119}{2} = -.06 \text{ KSI}$$

$$S_{12} = 13.47 - 1.15 = 12.32 \text{ KSI}$$

$$S_{23} = 1.15 - (-0.06) = 1.21 \text{ KSI}$$

$$S_{31} = -.06 - 13.47 = -13.53 \text{ KSI}$$

$$P_m = |-13.53| = 13.53 \text{ KSI}$$

$$P_m \leq S_m$$

$$13.53 < 31.7 \text{ KSI} \qquad \text{O.K.}$$

BY______________ DATE_________ SUBJECT____ SHEET NO.___9___OF______

CHKD. BY_______ DATE_________ JOB NO.___________________

Bending Stress in Plate (P= 119 psig)

Max at joint 233 (not shown on plots)

$\sigma_1 = 21.12$ KSI

$\sigma_2 = 13.55$ KSI

$\sigma_3 = -.119$ KSI

$S_{12} = 21.12 - 13.55 = 7.57$ KSI

$S_{23} = 13.55 - .12 = 13.43$ KSI

$S_{31} = -.12 - 21.12 = -21.24$ KSI

$P_b = |-21.24| = 21.24$ KSI

$P_b \leq 1.5\ S_m$

$21.24 \leq 1.5(27.7) = 41.5$ KSI O.K.

SHEET NO. 10 OF

BY DATE SUBJECT

CHKD. BY DATE JOB NO.

- tner Bar

Max stress Joint 54 (not shown on stress plot)

(P = 119 psig) (Bar A)

$\sigma_1 = 0.10$ KSI

$\sigma_2 = -37.52$ KSI

$\sigma_3 = 0$

$S_{12} = 0.10 - (-37.52) = 37.62$ KSI

$S_{23} = -37.52 - 0 = 37.52$ KSI

$S_{31} = 0 - 0.10 = -0.10$ KSI

$P_b = |37.62| = 37.62$ KSI

$P_b \leq 1.5\ S_m$

$37.62 \leq 1.5(31.7) = 47.5$ KSI O.K.

BY ________ DATE ________ SUBJECT ________ SHEET NO. 11 OF ____

CHKD. BY ______ DATE ________ JOB NO. ________

For relative displacement between the sealing surfaces of the door and plenum opening for internal P = 119 psi see Table 1 p. 12 of Finite Element Analyses of Access Door Reinforcement (Plenum).

For relative displacement between sealing surfaces of the door and plenum opening for vacuum along with dog loads under under vacuum, see Table 2 p. 14 of Finite Element Analysis of Access Reinforcement (Plenum).

BY________ DATE________ SUBJECT________ SHEET NO. 12 OF______
CHKD. BY______ DATE________ JOB NO.________

Hydro Test

The max primary stress in the Door at P= 119 psig is 21.12 KSI

Pressure on Door during hydro test.

$$P_H = 1.5(119) + 62.4\left(\frac{1}{144}\right)\left[\frac{41}{2} + 4.5\right]$$

$$P_H = 178.5 + 10.83$$

$$P_H = 189.3 \text{ psi}$$

stress at hydro

$$S = \frac{189.3}{119}(21.12) = 33.59 \text{ psi}$$

$$S < .8\,\sigma_{yp}$$

$$33.59 < .8(52.5) = 42 \text{ KSI (auto weld)}$$

∴ The Door meets the hydro test criteria.

JRRadkin 13.
7/12/96

BUCKLING OF 5'x12' DOOR STIFFENER'S

use simply supported Beam Analysis:

for 18" section of door:-

$$M = \frac{wl^2}{8} = \frac{\left(119 \frac{lbF}{in^2}\right)(18in)(102in)^2}{8} = 3.123 \times 10^6 in\text{-}lbF$$

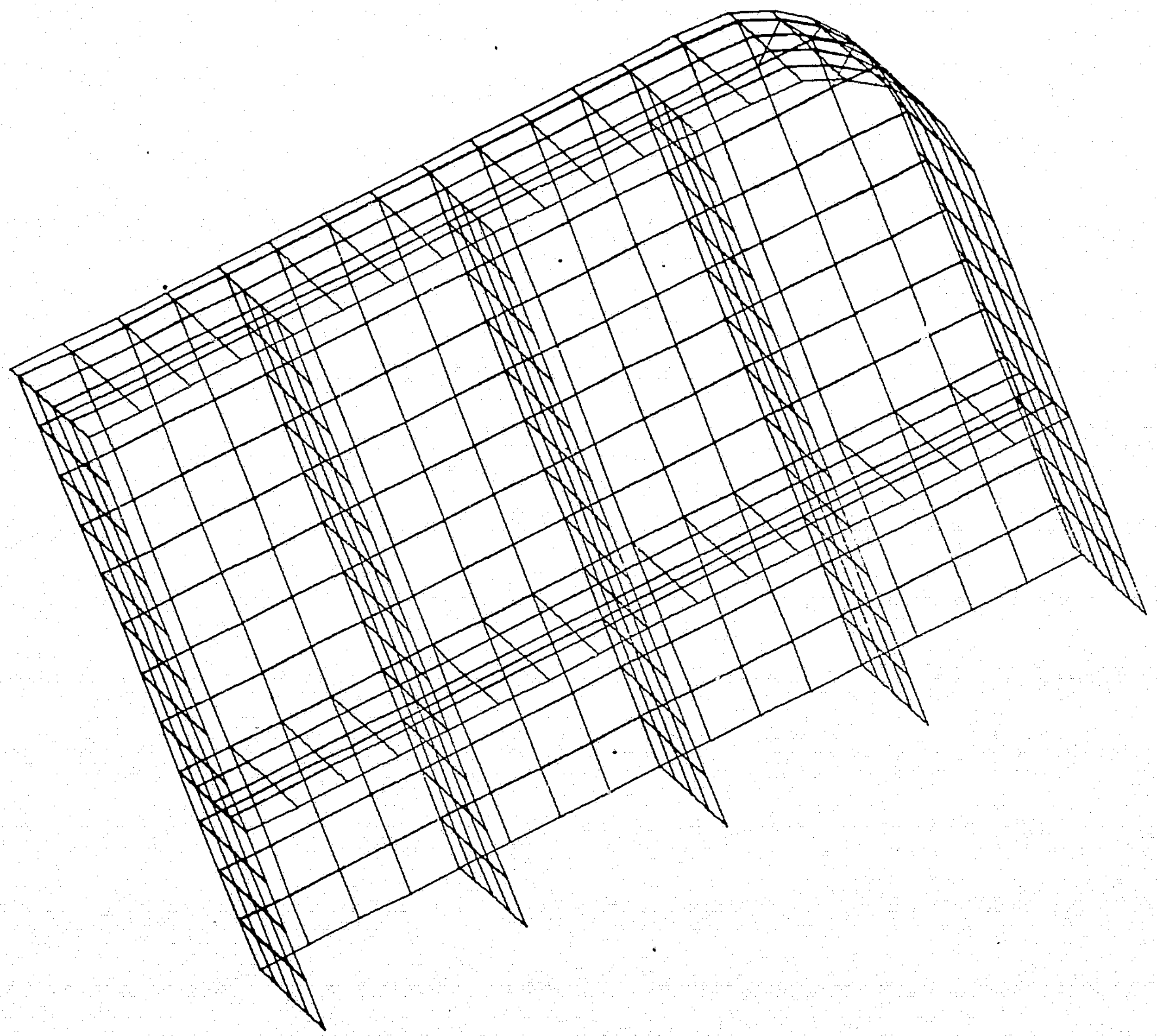
From Roark Case 15 Sect XV p. [illegible]
with ends held vertical not fixed [illegible] horiz plane

$$M' = \frac{\pi b^3 d \sqrt{EG\,(1 - .63\,b/d)}}{6L}$$

$$= \frac{(1.5in)^3 [illegible] \sqrt{\left(29 \times 10^6 \frac{lbF}{in^2}\right)\left(11.15 \times 10^6 [illegible]\right)\left(1 - .63 \frac{[illegible]}{[illegible]}\right)}}{(6)(102in)}$$

$M' = 1.198 \times 10^7$ in-lbF

[illegible] moment is less than critical moment.
[illegible] is conservative because it neglects restraint [illegible] plate.

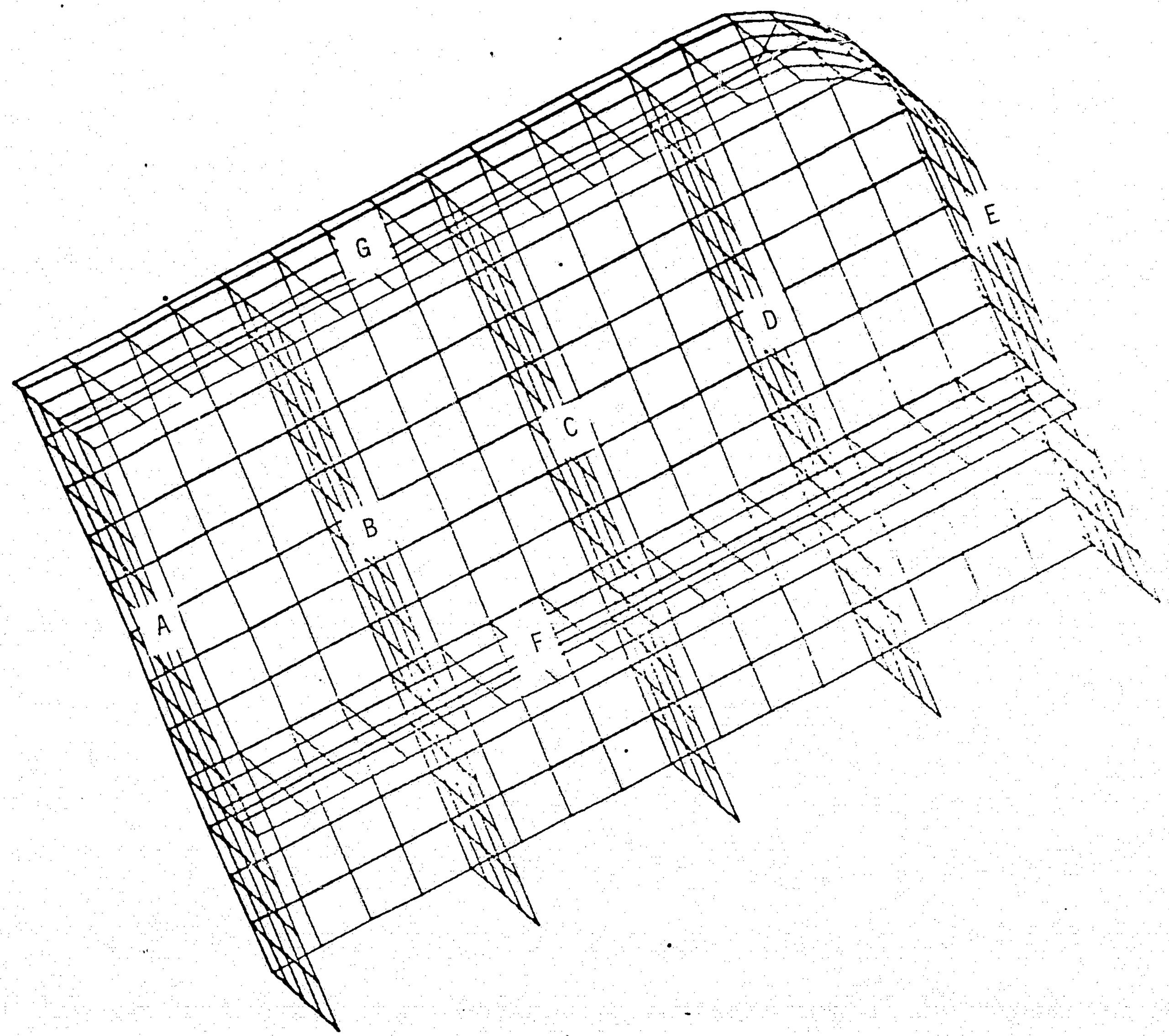


SPEC
1.1

NTF 9 X 12 DOORS

0 13
SCALE

Figure 1 A

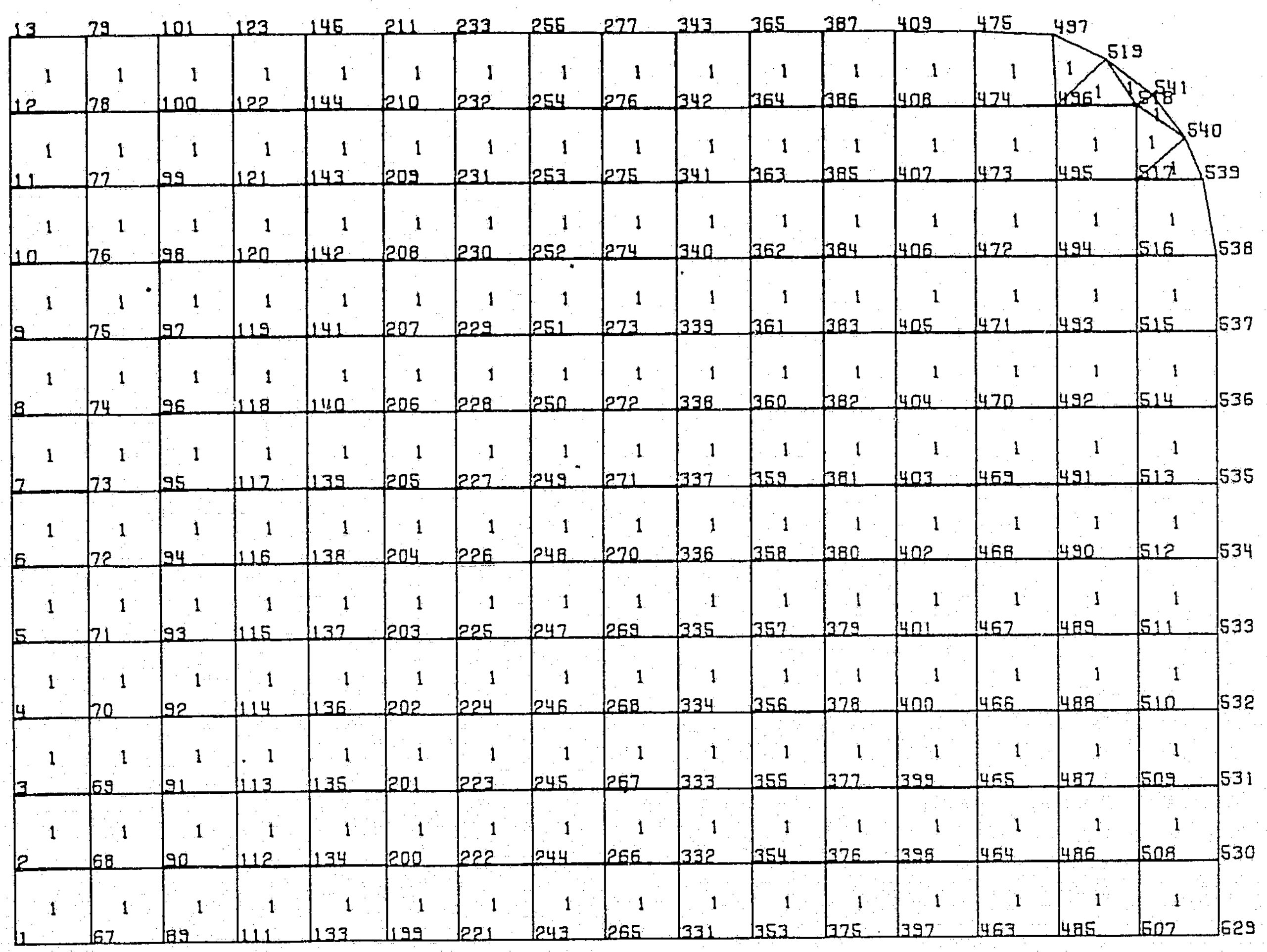


SPEC 1.1

NTF 9 X 12 DOORS

0 13
SCALE

Figure 1 B



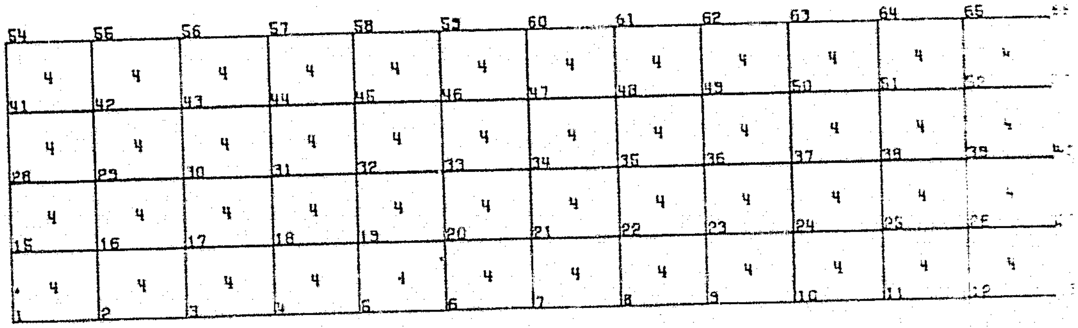
SPEC 2.1

NTF 9 X 12 DOORS
PLATE ONLY

0 1
SCALE

ELEMENT SECTION PROPERTY GROUPS

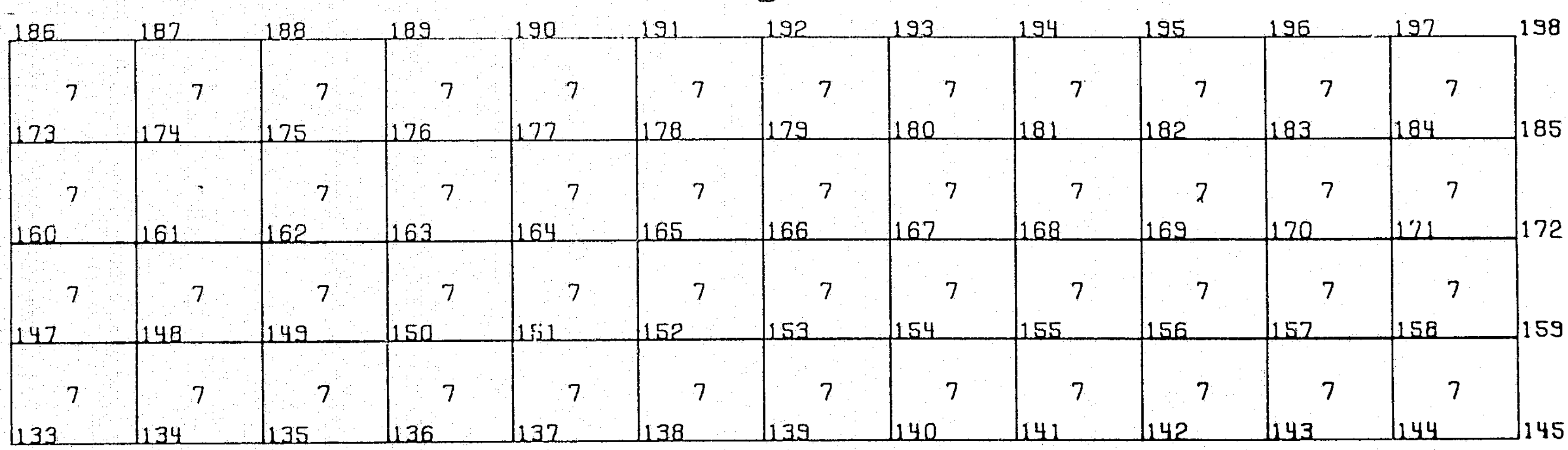
Figure 2



SPEC 3.1

NTF 9 X 12 DOORS
STIFFENER BAR A

Figure 3

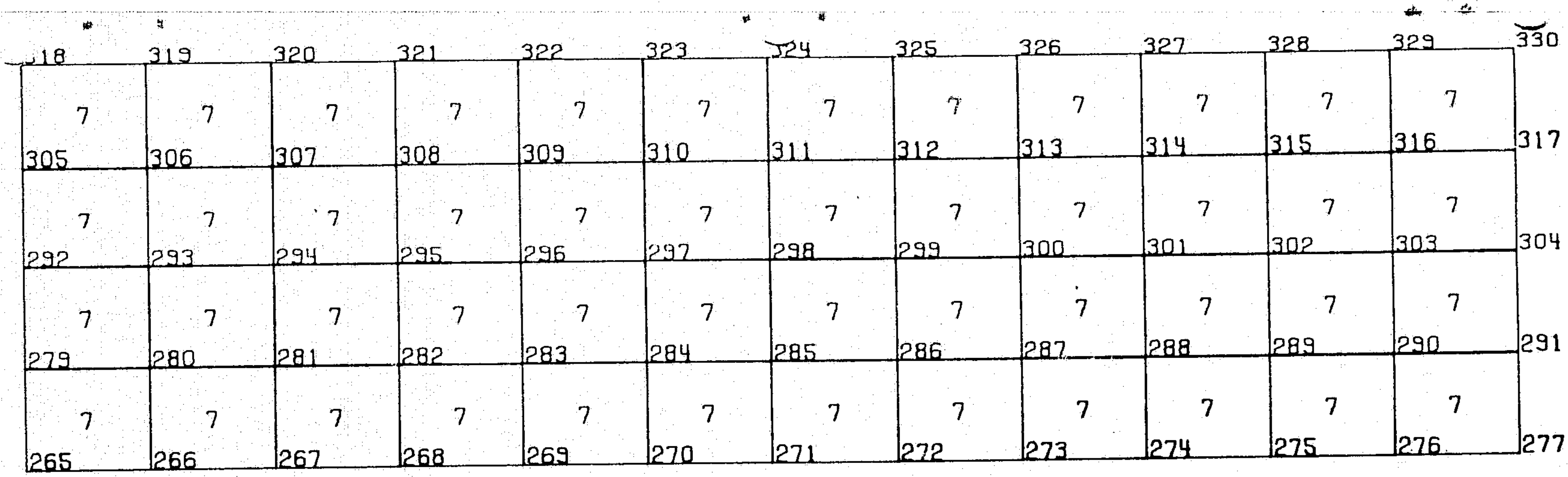


ELEMENT SECTION PROPERTY GROUPS

SPEC 4.1

NTF 9 X 12 DOORS
STIFFENER BAR B

0 8
SCALE



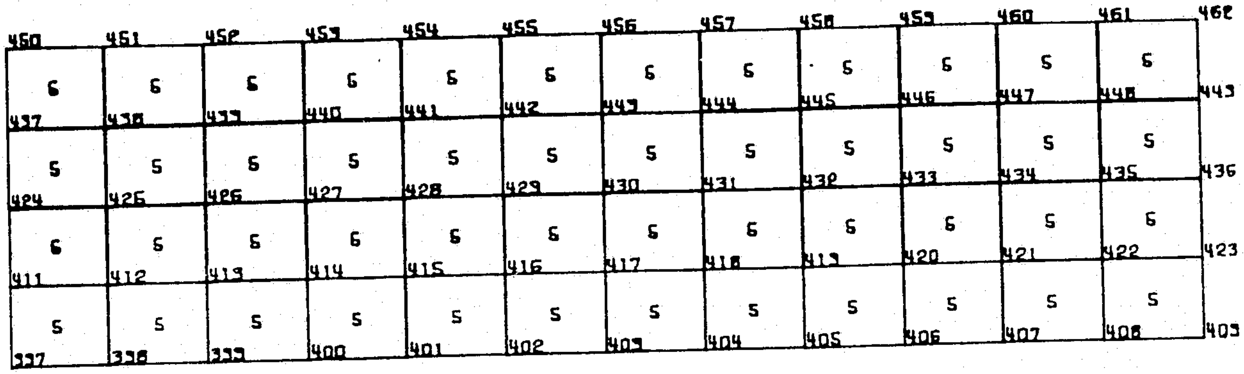
SPEC
5.1

NTF 9 X 12 DOORS
STIFFENER BAR C

0
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 3



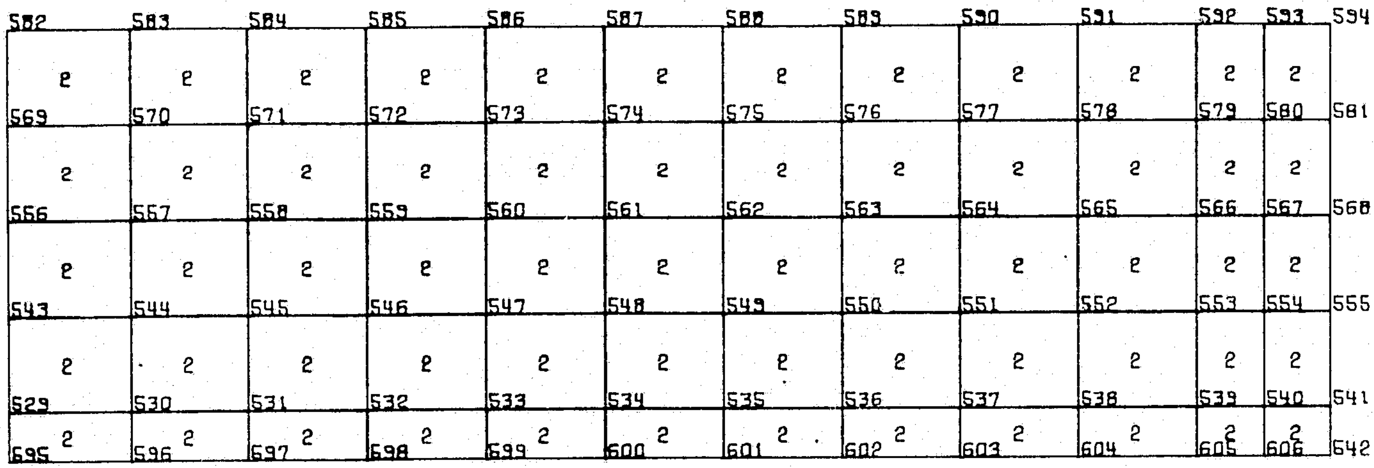
SPEC 6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 6

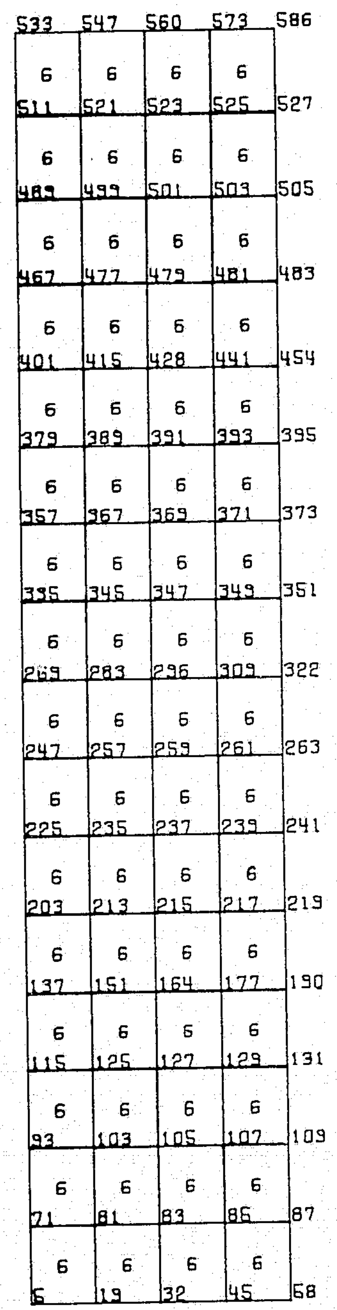


SPEC 7.1 NTF 9 X 12 DOORS
STIFFENER BAR E

0 8
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 7



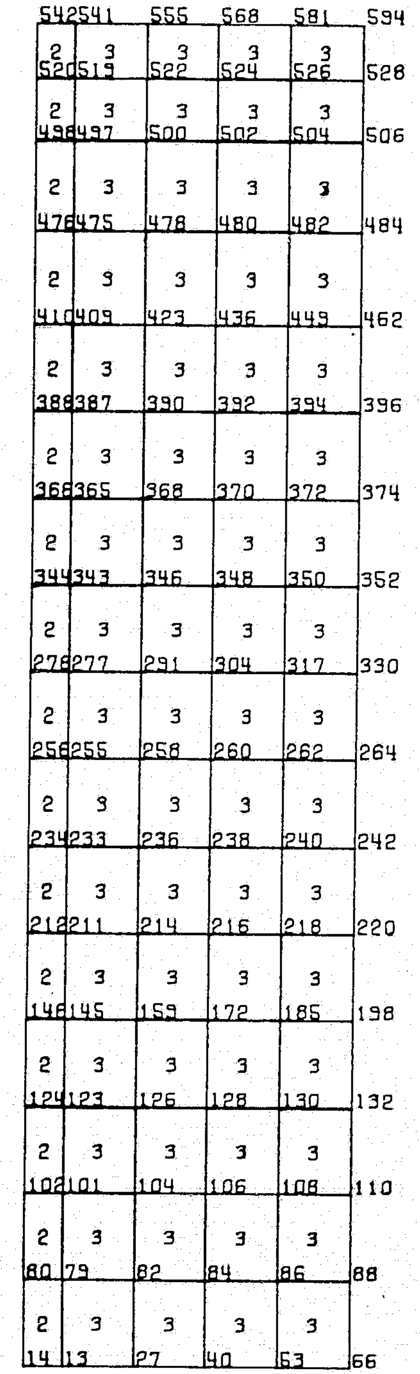
SPEC 8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 1
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 8



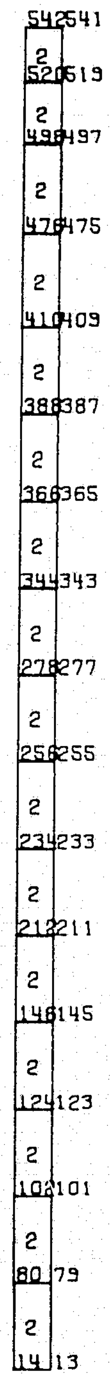
ELEMENT SECTION PROPERTY GROUPS

SPEC
9.1

NTF 9 X 12 DOORS
STIFFENER BAR G

0 11
SCALE

Figure 9



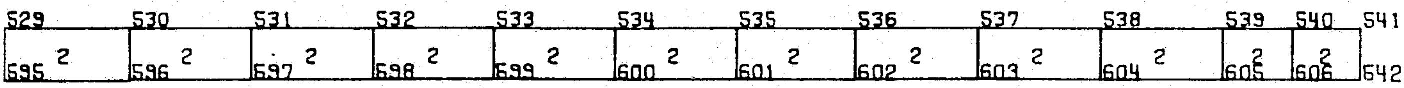
ELEMENT SECTION PROPERTY GROUPS

'EC
].1

NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 10



SPEC 11.1

NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

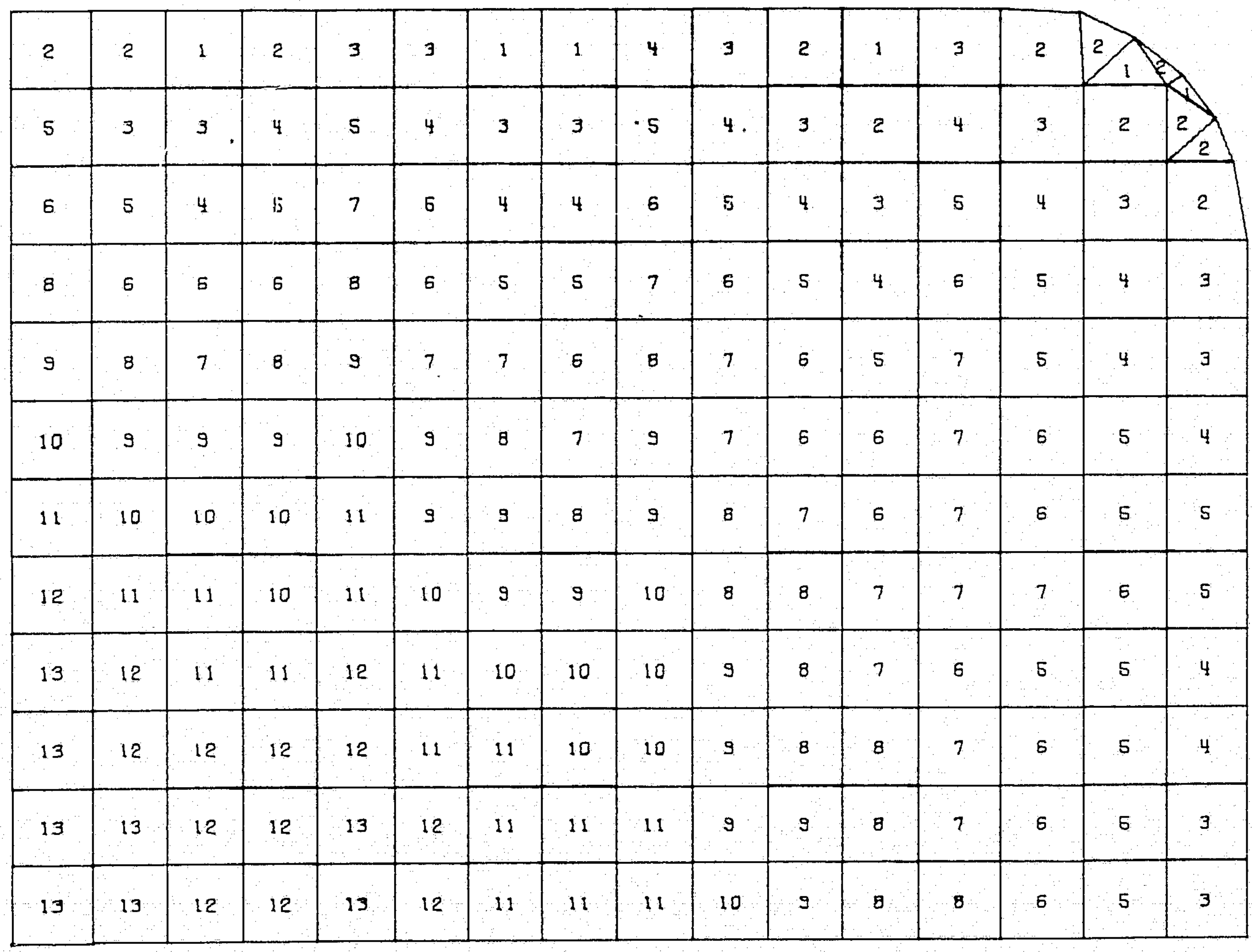
0 8
SCALE

ELEMENT SECTION PROPERTY GROUPS

Figure 11

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 0



SPEC 2.1

NTF 9 X 12 DOORS
PLATE ONLY

0 11
SCALE

Figure 12

10 / 1 / 1

DISPLAY= PS1 / 1000 , NODE= 1 , SURFACE= 1

4	0	-2	2	5	0	-2	1	6	1	-1	1	6	-1	1 / -1	1 / 0
14	-2	-2	1	14	-2	-3	1	14	-1	-3	0	13	-2	-2	4 / 1
18	1	-1	3	18	1	-1	2	18	1	-1	1	18	-1	-3	0
19	3	1	4	19	3	0	3	19	3	0	2	20	1	-3	0
18	5	2	4	19	5	1	3	19	4	0	2	20	2	-3	0
16	6	2	5	17	6	1	3	17	5	0	2	17	3	-2	0
12	8	5	5	12	8	4	4	12	7	3	2	10	6	1	2
7	14	19	13	7	13	19	12	6	13	17	11	4	14	19	9
14	7	6	8	14	6	5	7	11	4	3	5	7	1	1	3
16	6	6	8	16	6	4	7	14	4	2	5	14	-1	-1	2
18	8	6	9	17	7	5	8	17	6	3	6	18	1	-2	1
18	9	6	9	18	8	5	8	17	6	3	6	19	2	-2	0

SPEC
2.1

NTF 9 X 12 DOORS
PLATE ONLY

0 11
SCALE

Fig 13

10 / 1 / 1

DISPLAY= PS1 / 1000 , NODE= 1 , SURFACE= 2

1	5	5	3	2	6	5	2	2	6	5	2	1	6	3 4	-2
-1	8	8	6	-1	9	8	5	-1	9	9	4	-1	8	8	-1 3 3
1	8	10	8	1	9	11	6	1	9	11	5	-1	9	12	5
3	9	12	9	3	9	12	8	2	9	12	6	0	9	13	6
5	11	13	11	4	10	13	10	3	10	13	8	1	9	13	7
7	12	15	13	6	12	14	12	5	10	13	10	2	9	13	8
10	12	15	14	10	11	13	13	9	9	11	10	7	7	10	8
17	8	2	8	16	7	0	6	14	5	0	3	11	3	-3	3
11	17	16	15	10	16	15	13	8	13	12	9	5	10	8	5
10	18	18	15	9	17	17	13	7	15	14	10	3	12	12	6
10	17	18	16	10	16	17	14	8	13	14	10	3	11	14	6
10	16	18	16	10	15	17	14	8	13	14	11	3	10	14	6

SPEC 2.1

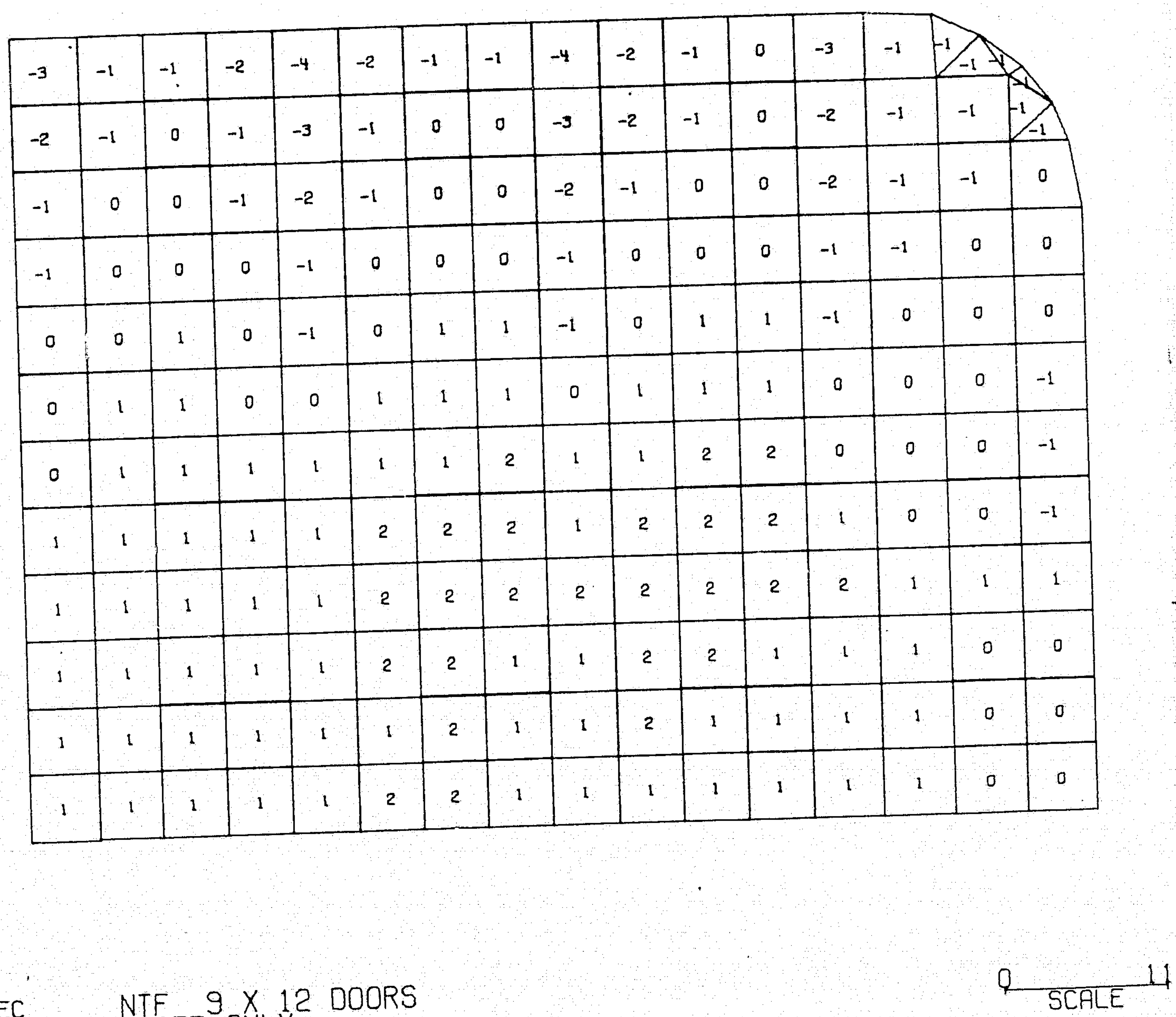
NTF 9 X 12 DOORS
PLATE ONLY

0 ——— 11
SCALE

Figure 14

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0



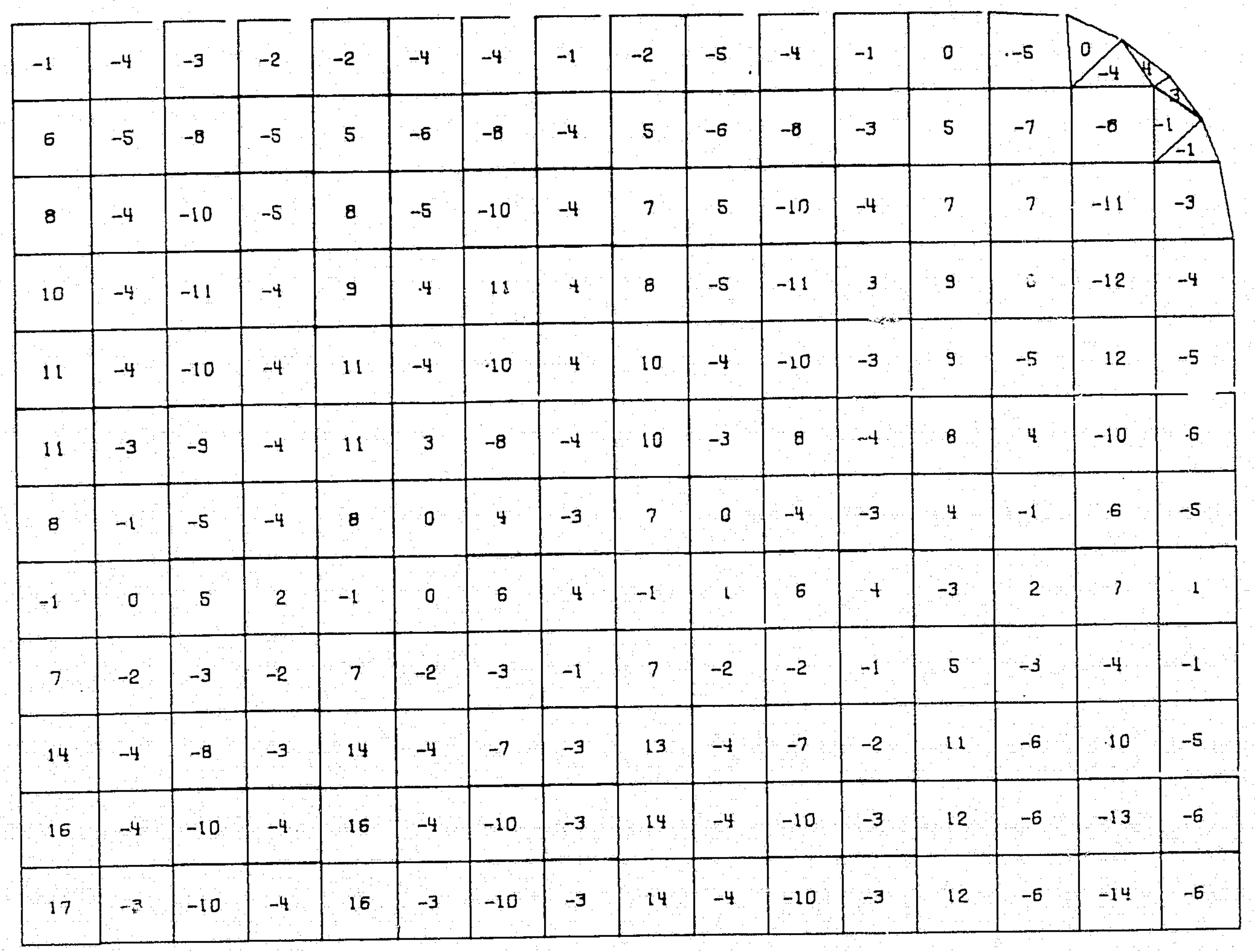
SPEC
2.1

NTF 9 X 12 DOORS
PLATE ONLY

Figure 15

10/1/1

DISPLAY= PS2 /1000 , NODE= 1, SURFACE= 1



SPEC 2.1

NTF 9 X 12 DOORS
PLATE ONLY

0 11
SCALE

Figure 16

10 / 1 / 1

DISPLAY= PS2 / 1000 , NODE= 1 , SURFACE= 2

-5	1	0	-1	-6	0	0	0	-7	0	1	1	-6	2	-2 2	-12 -10
-14	3	7	2	-14	3	7	3	-14	3	6	3	-13	4	5	-4 0
-17	4	9	3	-17	3	9	4	-17	3	8	4	-17	4	8	2
-18	4	11	4	-18	4	10	4	-17	4	9	4	-19	4	8	4
17	5	11	4	-17	4	11	5	-16	4	10	5	18	4	9	4
-14	5	10	5	-14	5	11	6	-13	4	10	6	-14	4	9	4
-8	2	7	6	-8	3	7	6	-7	3	7	6	-6	1	5	3
3	3	-2	-1	3	3	-2	0	4	1	-4	0	5	-5	-11	-4
-5	5	6	4	-5	5	6	4	-3	6	6	4	-2	5	5	2
-12	6	10	6	-12	7	11	6	-11	7	11	5	-12	7	10	5
-15	6	13	6	-15	7	13	6	-14	7	12	5	-16	7	11	5
-16	6	13	6	-15	6	13	6	-14	7	13	5	-17	7	11	6

SPEC
2.1

NTF 9 X 12 DOORS
PLATE ONLY

0 11
SCALE

Fig 17

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0

0	0	0	1	-3	1	0	1	1	1	1	2
0	0	1	0	-1	1	2	2	3	3	4	5
1	2	2	3	3	4	5	5	6	6	7	6
14	13	13	13	12	12	11	11	10	9	8	6

SPEC 3.1

NTF 9 X 12 DOORS
STIFFENER BAR A

0 — 8 SCALE

Figure 13

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 1 10/1/1

0	0	0	1	-3	1	0	1	1	1	1	2
0	0	1	0	-1	1	2	2	3	3	4	5
1	2	2	3	3	4	5	5	6	6	7	6
14	13	13	13	12	12	11	11	10	9	8	6

SPEC 3.1 TF 9 X 12 DOORS STIFFENER BAR A

0 8 SCALE

Figure 19

10 / 1 / 1

DISPLAY= PS1 / 1000 , NODE= 1 , SURFACE= 2

0	0	0	1	-3	1	0	1	1	1	1	2
0	0	1	0	-1	1	2	2	3	3	4	5
1	2	2	3	3	4	5	5	6	6	7	6
14	13	13	13	12	12	11	11	10	9	8	6

SPEC 3.1

NTF 9 X 12 DOORS
STIFFENER BAR A

0 8
SCALE

Figure 20

10 / 1 / 1

DISPLAY= PS2 / 1000 , NODE= 1 , SURFACE= 0

-24	-24	-24	-22	-21	-20	-17	-15	-12	-9	-6	-3
-12	-12	-11	-11	-11	-10	-9	-8	-8	-7	-6	-5
1	0	-1	-2	-2	-3	-3	-4	-4	-5	-6	-7
1	1	1	0	1	0	0	-1	-2	-3	-4	-6

0 8
SCALE

SPEC
3.1

NTF 9 X 12 DOORS
STIFFENER BAR A

Figure 21

10 / 1 / 1

)ISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1

-24	-24	-24	-22	-21	-20	-17	-15	-12	-9	-6	-3
-12	-12	-11	-11	-11	-10	-9	-8	-8	-7	-6	-5
1	0	-1	-2	-2	-3	-3	-4	-4	-5	-6	-7
1	1	1	0	1	0	0	-1	-2	-3	-4	-6

SPEC
3.1

NTF 9 X 12 DOORS
STIFFENER BAR A

0 8
SCALE

Figure 22

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

-24	-24	-24	-22	-21	-20	-17	-15	-12	-9	-6	-3
-12	-12	-11	-11	-11	-10	-9	-8	-8	-7	-6	-5
1	0	-1	-2	-2	-3	-3	-4	-4	-5	-6	-7
1	1	1	0	1	0	0	-1	-2	-3	-4	-6

SPEC
13.1

NTF 9 X 12 DOORS
STIFFENER BAR A

0 8
SCALE

Figure 23

10 / 1 / 1

DISPLAY= PS1 / 1000 , NODE= 1 , SURFACE= 0

0	0	0	1	-2	1	0	1	1	1	1	2
0	0	1	0	-1	1	1	2	3	3	4	5
1	2	2	2	3	4	4	5	6	6	6	6
13	13	12	12	12	11	11	10	9	9	8	6

SPEC
4.1

NTF 9 X 12 DOORS
STIFFENER BAR B

0 8
SCALE

Figure 24

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1

10/1/1

0	0	0	0	-2	1	1	1	1	1	1	2
0	1	1	0	0	1	2	2	3	3	4	4
1	2	2	2	3	4	4	5	6	6	6	6
13	13	12	12	11	11	11	10	9	9	8	6

SPEC 4.1

NTF 9 X 12 DOORS
STIFFENER BAR B

0 8
SCALE

Figure 25

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2

0	0	0	1	-3	0	0	1	1	1	1	2
0	0	0	0	-1	0	1	2	2	3	4	5
1	1	2	2	3	4	4	5	6	6	6	6
13	13	12	12	12	11	11	10	9	9	8	6

SPEC
4.1

NTF 9 X 12 DOORS
STIFFENER BAR B

0 8
SCALE

Figure 26

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

-23	-23	-23	-21	-20	-19	-17	-14	-12	-9	-6	-3
-11	-11	-11	-10	-10	-9	-9	-8	-7	-7	-6	-5
0	0	-1	-2	-2	-3	-3	-4	-4	-5	-5	-6
1	1	1	0	0	0	0	-1	-2	-2	-4	-5

SPEC 4.1

NTF 9 X 12 DOORS
STIFFENER BAR B

0 8
SCALE

Figure 27

10 / 1 / 1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1

-23	-23	-22	-21	-19	-18	-16	-14	-12	-9	-6	-4
-11	-11	-11	-10	-9	-9	-9	-8	-7	-7	-6	-6
1	0	-1	-2	-2	-2	-3	-3	-4	-5	-5	-6
2	1	1	0	0	0	0	-1	-1	-2	-4	-5

PEC
.1

NTF 9 X 12 DOORS
STIFFENER BAR B

0 8
SCALE

Figure 28

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

-23	-23	-23	-21	-21	-19	-17	-14	-12	-9	-6	-3
-11	-11	-11	-10	-11	-10	-9	-8	-7	-7	-6	-5
0	0	-1	-2	-2	-3	-3	-4	-4	-5	-6	-6
1	1	1	0	1	0	0	-1	-2	-3	-4	-5

0 8
SCALE

SPEC 4.1 NTF 9 X 12 DOORS
STIFFENER BAR B

Figure 29

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0

10/1/1

0	0	0	0	-2	1	0	1	1	1	1	2
0	0	1	0	0	1	1	2	2	3	4	4
1	2	2	2	2	3	3	4	5	5	6	5
11	11	10	9	9	9	9	9	8	8	7	5

SPEC 5.1

NTF 9 X 12 DOORS
STIFFENER BAR C

0 8
SCALE

Figure 30

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1

0	0	0	0	-1	1	1	1	1	1	1	1
1	1	1	0	0	1	1	2	2	3	3	4
1	2	2	2	2	3	4	4	5	5	6	5
11	11	10	9	6	9	9	9	8	8	7	5

SPEC 5.1

NTF 9 X 12 DOORS
STIFFENER BAR C

0 SCALE 8

Figure 31

10 / 1 / 1

DISPLAY= PS1 / 1000 , NODE= 1 , SURFACE= 2

0	0	0	1	-2	0	0	0	1	1	1	2
0	0	0	0	0	0	1	1	2	3	4	5
1	1	2	2	2	2	3	4	5	5	6	6
10	10	10	9	10	9	9	8	8	7	6	5

SPEC 5.1   NTF 9 X 12 DOORS
STIFFENER BAR C

0 8
SCALE

Figure 32

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0 10/1/1

-19	-19	-19	-18	-16	-15	-14	-12	-10	-8	-5	-3
-9	-9	-9	-9	-8	-8	-7	-7	-6	-6	-5	-5
0	0	-1	-2	-1	-2	-2	-3	-3	-4	-5	-5
1	1	1	0	0	0	0	0	-1	-2	-3	-5

SPEC
5.1

NTF 9 X 12 DOORS
STIFFENER BAR C

0 8
SCALE

Figure 33

DISPLAY= PS2 / 1000 , NODE= 1 , SURFACE= 1

-19	-19	-19	-18	-14	-14	-13	-12	-10	-8	-6	-4
-9	-9	-9	-9	-7	-7	-7	-6	-6	-6	-6	-5
1	0	0	-1	-2	-2	-2	-3	-3	-4	-5	-6
2	2	2	0	0	0	0	0	-1	-2	-3	-5

SPEC
5.1

NTF 9 X 12 DOORS
STIFFENER BAR C

0 8
SCALE

Figure 34

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

-20	-19	-19	-17	-19	-17	-15	-12	-10	-7	-4	-2
-10	-10	-9	-8	-9	-9	-8	-7	-6	-6	-5	-4
0	-1	-1	-2	-1	-2	-3	-3	-4	-4	-5	-5
0	0	0	0	1	0	0	-1	-1	-2	-4	-4

SPEC 5.1

NTF 9 X 12 DOORS
STIFFENER BAR C

0 8
SCALE

Figure 35

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0 10/1/1

0	0	0	0	-1	0	0	0	0	1	1	1
0	1	1	1	0	0	1	1	1	2	3	3
1	2	2	2	1	1	2	3	3	4	4	4
8	8	7	6	5	6	6	6	6	6	5	4

SPEC
6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

Figure 36

10 / 1 / 1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1

0	0	0	0	0	1	0	0	0	1	1	1
1	1	1	0	-1	1	1	1	1	2	2	2
2	2	3	2	0	2	2	3	3	4	4	4
8	8	7	7	3	7	6	6	6	6	6	4

SPEC 6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

Figure 37

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2

0	0	0	1	-1	-1	0	0	0	1	1	2
0	0	1	1	0	0	0	1	1	2	3	4
1	1	2	2	2	1	2	3	3	4	4	4
7	7	7	5	7	5	6	6	6	5	4	4

SPEC 6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

Figure 38

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

-13	-12	-12	-11	-10	-10	-9	-8	-7	-6	-4	-2
-6	-6	-6	-5	-5	-5	-4	-4	-4	-4	-4	-3
1	0	-1	-1	0	0	-1	-1	-2	-2	-3	-4
1	1	1	0	0	0	1	0	0	-1	-2	-3

SPEC
6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

Figure 39

10 / 1 / 1

DISPLAY= PS2 / 1000 , NODE= 1 , SURFACE= 1

-12	-12	-12	-11	-6	-8	-8	-8	-7	-6	-5'	-4
-6	-6	-6	-6	-3	-3	-4	-4	-4	-4	-4	-5
1	0	0	-1	-1	0	0	-1	-2	-2	-3	-4
2	2	2	1	0	1	1	0	0	0	-1	-3

SPEC 6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

Figure 40

10 / 1 / 1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

-13	-13	-12	-10	-14	-12	-10	-9	-7	-5	-3	-1
-6	-6	-6	-5	-7	-6	-5	-5	-4	-4	-3	-2
0	-1	-1	-2	1	-1	-1	-1	-2	-3	-3	-3
1	1	0	-2	0	0	1	1	0	-1	-3	-3

SPEC 6.1

NTF 9 X 12 DOORS
STIFFENER BAR D

0 8
SCALE

Figure 41

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0

1	1	0	0	0	0	0	0	0	0	0	0
1	1	1	2	1	1	1	0	1	1	1	0
1	1	2	3	2	2	2	2	2	1	1	1
1	2	2	4	4	2	4	4	4	3	2	2
2	2	4	5	2	6	1	7	7	5	5	5

SPEC 7.1 NTF 9 X 12 DOORS
STIFFENER BAR E

0 8
SCALE

Figure 42

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1

3	3	2	0	3	2	1	1	1	-1	-2	-2
3	3	3	1	0	3	3	2	2	1	-1	-1
4	4	4	3	-1	4	5	5	6	5	3	2
6	7	5	6	0	4	7	9	12	8	7	6
2	2	4	5	5	5	1	7	7	4	4	3

SPEC 7.1

NTF 9 X 12 DOORS
STIFFENER BAR E

0 8
SCALE

Figure 43

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 2

-1	-1	0	1	0	-1	-1	-1	0	3	5	5
-2	-1	0	2	2	-1	-1	-1	-1	2	3	4
-1	-1	0	2	5	1	0	-1	-2	-1	0	1
-1	-1	-1	1	8	0	2	1	1	0	-1	0
2	2	3	5	-1	6	1	6	7	5	6	7

SPEC 7.1

NTF 9 X 12 DOORS
STIFFENER BAR E

0 8
SCALE

Figure 44

10 / 1 / 1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

0	0	0	-1	0	-1	-1	-2	-2	-2	-1	-1
0	0	-1	-1	0	-1	-1	-1	-1	-2	-2	-1
0	0	-1	-2	-2	-2	-1	0	0	-1	-2	-2
-1	0	-2	0	-5	-1	-2	0	3	0	0	0
-3	0	-5	0	-15	2	-5	0	5	-1	0	0

SPEC 7.1

NTF 9 X 12 DOORS
STIFFENER BAR E

0 8
SCALE

Figure 45

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1

1	1	0	-2	0	1	0	0	-3	-6	-8	-7
2	2	1	-2	-2	0	1	1	-1	-4	-5	-5
4	3	2	-1	-3	0	2	2	1	0	-2	-3
4	4	4	4	-5	2	3	4	5	6	4	3
-3	0	-6	-1	-15	2	-5	0	4	-1	0	0

0 8 SCALE

SPEC NTF 9 X 12 DOORS
7.1 STIFFENER BAR E

Figure 46

10 / 1 / 1

DISPLAY= PS2 / 1000 , NODE= 1 , SURFACE= 2

-2	-2	-1	0	-3	-3	-3	-3	-1	1	2	2
-2	-2	-2	-1	1	-2	-3	-3	-2	0	0	1
-4	-4	-4	-2	0	-3	-4	-4	-3	-4	-3	-2
-7	-6	-8	-4	-6	-4	-8	-7	-4	-7	-7	-6
-3	0	-5	1	-15	2	-5	1	5	-1	0	0

SPEC 7.1

NTF 9 X 12 DOORS
STIFFENER BAR E

0 8
SCALE

Figure 47

10 / 1 / 1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0

5	3	2	1
5	4	2	1
4	2	1	0
3	2	1	1
2	1	0	0
2	1	0	0
1	0	0	0
0	0	1	2
1	0	0	0
1	1	0	0
1	1	0	0
-1	0	1	3
1	1	0	0
1	1	0	0
1	1	1	0
-2	0	1	3

SPEC 8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 11
SCALE

Figure 48

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE=

6	3	1	0
5	4	2	1
5	3	2	1
2	2	1	1
3	1	0	-1
3	1	0	0
2	1	1	0
-1	-1	1	2
2	0	0	-1
2	1	0	0
2	1	0	0
-1	-1	1	2
2	1	0	-1
2	1	0	0
2	1	0	-1
0	-1	1	2

SPEC
8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 11
SCALE

Figure 49

10/1/1.

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2

4	3	3	2
4	3	2	1
3	2	1	0
4	2	1	0
2	1	1	1
2	1	0	0
0	0	0	-1
1	1	1	2
0	0	1	0
1	1	0	0
0	0	0	0
0	1	2	3
0	1	1	0
0	1	0	0
0	0	1	0
-1	1	2	4

SPEC 8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 11
SCALE

Figure 50

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

-4	-4	-3	-2
-2	-4	-4	-3
-2	-3	-4	-5
-2	-3	-5	-7
-1	-2	-4	-7
0	-3	-5	-8
0	-3	-5	-8
-1	-3	-6	-9
-1	-3	-6	-9
0	-4	-6	-8
-1	-4	-6	-8
-2	-3	-6	-8
-2	-4	-6	-8
-2	-4	-6	-8
-2	-4	-6	-8
-3	-4	-6	-8

SPEC 8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 11
SCALE

Figure 51

10 / 1 / 1

DISPLAY= PS2 / 1000 , NODE= 1 , SURFACE= 1

-4	-4	-4	-4
-1	-4	-4	-4
-1	-2	-3	-4
-3	-3	-3	-3
0	-2	-5	-8
0	-2	-5	-8
1	-2	-5	-7
-2	-3	-5	-7
0	-3	-6	-9
0	-3	-6	-8
0	-3	-6	-8
-4	-5	-6	-8
-1	-3	-6	-8
-1	-4	-6	-8
-1	-4	-6	-8
-4	-5	-6	-8

SPEC
8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 11
SCALE

Figure 52

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE=

-5	-4	-2	0
-3	-5	-4	-3
-2	-4	-5	-7
-2	-3	-6	-10
-1	-2	-4	-7
-1	-3	-5	-8
-1	-3	-6	-9
-2	-2	-6	-10
-2	-3	-5	-8
-1	-4	-6	-8
-2	-4	-6	-9
-3	-2	-6	-9
-3	-4	-6	-8
-2	-5	-6	-8
-3	-5	-6	-8
-3	-2	-5	-8

SPEC 8.1

NTF 9 X 12 DOORS
STIFFENER BAR F

0 SCALE 11

Figure 53

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0

4	2	1	0	0
0	1	0	0	0
2	1	0	0	1
3	1	0	1	1
5	3	3	3	3
-7	0	3	3	4
5	1	2	3	4
4	1	1	2	5
7	3	3	4	6
-11	-1	3	5	7
6	2	3	5	7
5	2	3	5	7
7	3	2	5	7
-11	-1	3	5	8
6	2	3	5	8
5	3	4	5	8

SPEC 9.1 NTF 9 X 12 DOORS
STIFFENER BAR G

0 11
SCALE

Figure 54

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1 10/1/1

4	4	1	0	0
-1	3	2	2	3
2	3	2	2	3
2	-1	-1	0	2
6	6	3	3	2
-8	4	5	4	4
4	4	3	4	5
2	0	0	1	6
7	7	4	4	6
-11	3	5	6	7
6	5	4	5	8
2	1	1	3	7
7	6	3	5	7
-11	2	5	6	9
5	5	4	6	8
2	2	2	3	7

SPEC 9.1 NTF 9 X 12 DOORS STIFFENER BAR G

0 11 SCALE

Figure 55

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2

10/1/1

4	0	0	1	0
2	-1	-1	-1	-1
2	-1	-1	0	0
5	4	2	2	1
5	1	3	4	4
-7	-3	1	2	3
5	-2	0	2	3
7	4	3	3	4
7	0	3	5	6
-10	-5	1	4	6
6	-1	1	4	7
8	5	5	6	7
7	-1	2	5	7
-10	-5	1	4	8
6	-1	2	5	8
8	5	6	7	9

SPEC 9.1

NTF 9 X 12 DOORS
STIFFENER BAR G

0 11
SCALE

Figure 56

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

1	-1	-2	-1	0
-7	-4	-2	-1	0
-1	0	0	0	0
-2	0	0	0	0
5	-4	-5	-3	-1
-22	-12	-5	-2	-1
-10	-3	-1	-1	0
-3	-1	-1	0	1
5	-6	-6	-3	-1
-30	-16	-7	-3	-1
-15	-5	-2	-1	0
-3	-3	-3	0	1
5	-5	-5	-2	-1
-29	-15	-6	-2	-1
-15	-6	-3	-1	0
-3	-4	-3	0	1

SPEC 9.1

NTF 9 X 12 DOORS
STIFFENER BAR G

0 11
SCALE

Figure 57

10/1/1

ISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1

1	1	-2	-1	0
-7	0	0	0	1
0	2	1	0	0
-2	-2	-2	-1	-1
5	-2	-5	-4	-2
-21	-7	-4	-2	-1
-9	-1	0	-1	0
-3	-5	-4	-1	0
6	-2	-6	-4	-2
-29	-10	-5	-3	-1
-14	-3	-1	-1	-1
-3	-7	-5	-1	0
6	-1	-5	-3	-2
-29	-9	-5	-3	-1
-19	-3	-1	-2	-1
-3	-7	-6	-2	0

SPEC B.1 NTF 9 X 12 DOORS
STIFFENER BAR G

0 11
SCALE

Figure 58

10 / 1 / 1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

1	-4	-3	-1	0
-6	-8	-3	-2	-2
-2	-2	-1	-1	-2
-2	1	1	1	0
4	-7	-6	-3	0
-22	-18	-7	-3	0
-11	-5	-3	-1	-1
-3	0	1	2	2
4	-9	-7	-3	0
-30	-23	-8	-3	0
-17	-8	-3	-1	0
-4	-1	0	1	2
3	-8	-6	-2	0
-29	-22	-8	-2	0
-16	-8	-4	-1	0
-4	-2	-1	1	2

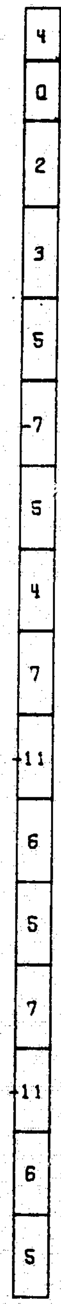
SPEC
9.1

NTF 9 X 12 DOORS
STIFFENER BAR G

0 11
SCALE

Figure 59

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 0 10/1/1



SPEC
10-1

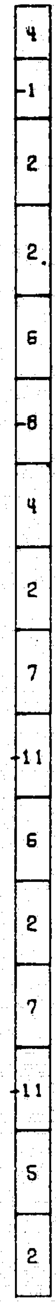
NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 60

10/1/1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 1



SPEC 10.1

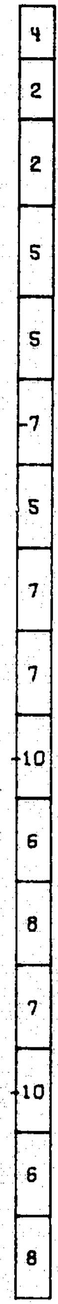
NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 61

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2



SPEC 10.1

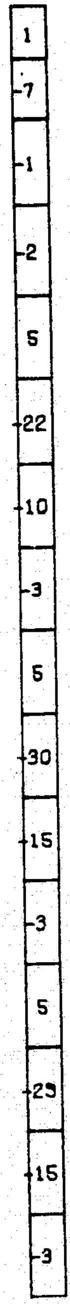
NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 62

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE=



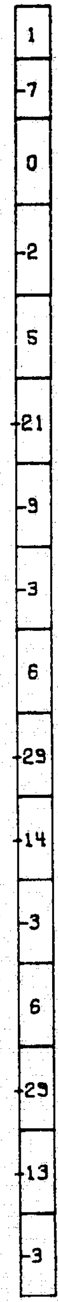
SPEC
10.1

NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 63

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1



SPEC
10.1

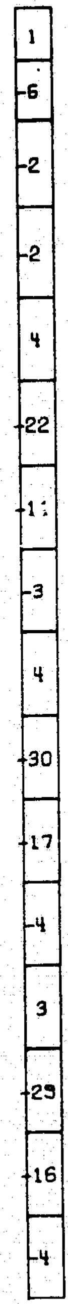
NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 64

10 / 1 / 1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2



SPEC
10.1

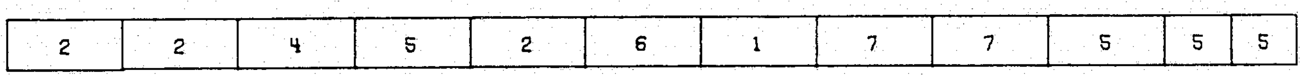
NTF 9 X 12 DOORS
SEAL FLANGE - TOP

0 11
SCALE

Figure 65

10 / 1 / 1

DISPLAY= PS1 /1000 , NODE= 1 , SURFACE= 0



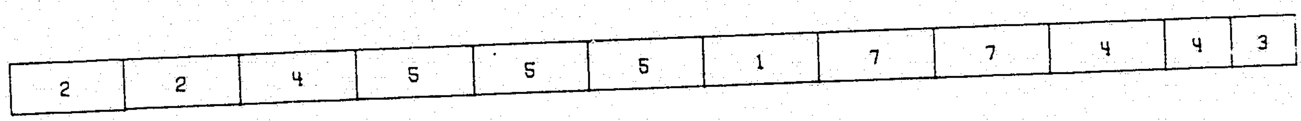
SPEC
11-1

NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

Figure 66

10 / 1 / 1

DISPLAY= PS1 / 1000 , NODE= 1 , SURFACE= 1



0 8
SCALE

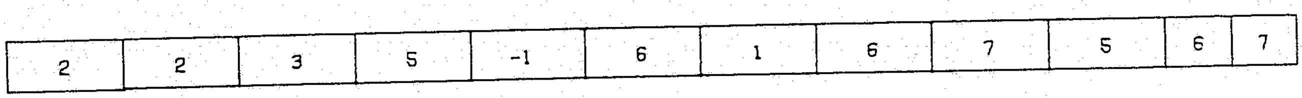
SPEC 11.1

NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

Figure 67

10/1/1

DISPLAY= PS1 /1000 , NODE= 1, SURFACE= 2



SPEC 11.1

NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

0 8
SCALE

Figure 68

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 0

10/1/1

-3	0	-5	0	-15	2	-5	0	5	-1	0	0

SPEC 11.1

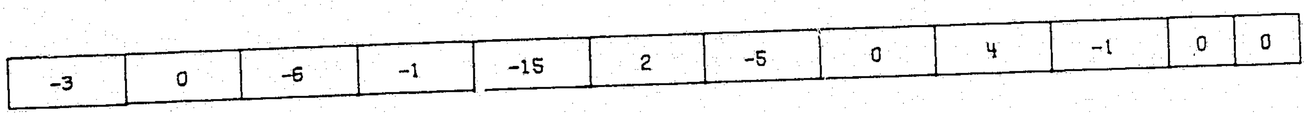
NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

0 8
SCALE

Figure 69

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 1



SPEC
11.1

NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

0 8
SCALE

Figure 70

10/1/1

DISPLAY= PS2 /1000 , NODE= 1 , SURFACE= 2

-3	0	-5	1	-15	2	-5	1	5	-1	0	0

SPEC
1.1

NTF 9 X 12 DOORS
SEAL FLANGE - SIDE

0 ____ 8
SCALE

Figure 71