LMSC-HEC TR F268584-IV

FINAL REPORT

SPACE SHUTTLE MAIN ENGINE STRUCTURAL ANALYSIS AND DATA REDUCTION/EVALUATION

VOLUME 4: HIGH PRESSURE FUEL TURBO-PUMP INLET HOUSING ANALYSIS

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by

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(NASA-CR-183667) SPACE SHUTTLE MAIN ENGINE STRUCTURAL ANALYSIS AND DATA REDUCTION/EVALUATION. VOLUME 4: HIGH PRESSURE FUEL TURBO-PUMP INLET HOUSING ANALYSIS Final Report (Lockheed Missiles G3/20 N89-27696 Unclas 0211798

FOREWORD

This volume of the final report summarizes the analysis performed on the SSME High Pressure Fuel Turbo-Pump (HPFTP) Inlet Housing. Three DIAL finite element models were built to aid in assessing the structural life of the welds and fillets at the vanes. This analysis was performed by Kirby V. Pool under Contract NAS8-37282.

Complete results are given; however, some assumptions were made in determining the maximum surge pressure and in some weld material properties in the static/fatigue analysis. Therefore more information is requested for the closure of this study.

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1. INTRODUCTION AND OVERVIEW

The SSME High Pressure Fuel Turbo Pump (HPFTP) contains several components that are highly stressed and subject to fatigue from cyclic loading. The Inlet Housing, which directs the flow of liquid hydrogen into the pump, is of particular concern because of the detection of cracks in the welded joints between the torus and the main body of the Inlet Housing (photographs of a sectioned Inlet Housing are shown in Figure 1). Whether these cracks occur as a result of fatigue loading from previous firings or from residual stresses due to the initial welding process, they are significant enough to require weld repair.

The process of weld repair creates some additional concern with regard to this part. During the weld repair process, the entire Inlet Housing is washed in an acid bath to clean and prepare the surfaces. This acid wash etches the grain boundaries of the titanium material, creating potential fatigue crack initiation sites. The existence of these micro-cracks could lead to a shorter high-cycle fatigue life for a given level of mean stress and cyclic loading. The purpose of this analysis was to assess the structural life of the areas around the welds and in the fillets of the vanes (which guide the flow of liquid hydrogen into the impellers).

Three DIAL (Ref. 1) finite element models were built for this analysis. A simple two-dimensional (2-D) model was constructed and analyzed as a first order estimate of the relative stress levels in the weld areas and in the vanes. The second model was a 360° global model, with simplified shell element vanes included, to determine where, around the circumference, the stresses are at a maximum. The third model was a detailed 3-D submodel of a slice of the global model through the region of maximum stress. This submodel included both of the critical weld areas, the torus shell, and one vane modeled in sufficient detail to include the fillets at the vane attachments. The purpose of this model was to provide more accurate stresses in the critical weld areas as well as in the vane fillets.

As mentioned earlier, the goal of this analysis was to determine, based on the stress levels in the regions of concern and on the signal-to-noise (S/N) curve and Modified Goodman Diagram for the titanium alloy (Ti-5Al-2.5Sn ELI), what the safe life for the SSME HPFTP Inlet Housing should be. The analysis predicts stresses in the vicinity of the vane fillets which exceed the yield strength of the material at Full Power Level (FPL). Although there appears to be a fairly comfortable margin of safety with respect to the ultimate elongation of the material, any appreciable cyclic component to the load will greatly limit the fatigue life of the part. A nonlinear, plastic analysis of the hardware should be performed to provide an accurate estimate of the static stress margin of safety. Furthermore, a detailed study to determine the cyclic loading environment within the Inlet Housing will be necessary to accurately assess the fatigue life of this part.

2. FINITE ELEMENT MODEL DESCRIPTION

This discussion includes the global 3-D model and the detailed vane submodel. Details of the DIAL 2-D finite element model are given in the March and April Progress Reports. Since this model was for preliminary analysis only, details will not be discussed in this Final Report.

2.1 GLOBAL MODEL

Figure 2 is a shaded light source plot of the DIAL global 3-D model of the HPFTP Inlet Housing. Figures 3 and 4 are hidden line mesh plots of the model. Figure 5 shows cutaway views of the main components of the model. Table 1 lists the model components, providing a count of the number of nodes, type and number of elements, and the total number of degrees of freedom (DOF). Note that this model uses linear, hybrid stress solid elements.

Table 1 NODE AND ELEMENT BREAKDOWN FOR HPFTP INLET HOUSING COMPONENTS (3-D GLOBAL MODEL)

Component	Drawing Number	Nodes	Elements
Inlet Housing Main Body (360)	RS007512 (Sheets 35,40,41)	7651	4950 solids
Torus (0 - 360)	RS007512 (Sheet 36)	1754	660 solids 920 shells
Support Structure	RS007687	153	70 solids 24 shells
Vanes	RS007512 (Sheet 45)	494	480 shells
	TOTALS	10052 (34980 DOF)	5680 solids 1424 shells

In several places in the model it was necessary to connect shell elements to solid elements. Figure 6 is a detail of a typical shell/solid interface which is designed to transmit moments as well as forces between the solid and shell elements. This type of interface is found in the torus portion of the model. The connection of the shell element vanes to the solid elements of the inner and outer rings (see Figure 4) was accomplished by extending the vane shell elements into the solid elements a depth of one element (thereby creating a moment resisting couple). Figure 7 shows this connection more clearly.

The refinement and thicknesses of the vane shell elements in the global model were established by means of a parametric study which attempted to match the stiffness of a typical "shell element" vane to that of the "solid element" vane in the detailed submodel. (The July Progress Report covers this study in detail.) Figure 8 depicts the final configuration for the global model vanes.

The DIAL runstream which generated the global model is included in Appendix A.

2.2 DETAILED VANE SUBMODEL

Plots of the detailed vane submodel are shown in Figures 9 through 11 (Figures 9a and 9B are light source shaded plots). The submodel comprises 8553 nodes, 1394 parabolic solid elements, and 286 parabolic shell elements, and has a total of 28446 DOF. The vane and fillets were modeled as accurately as possible, based on the dimensions provided in drawing number RS007512-131. A sensitivity study was performed which varied the element refinement in the fillets. The results discussed in the August Progress Report showed that the mesh density was adequate.

The DIAL runstream which generated the detailed vane submodel is included in Appendix B.

3. BOUNDARY CONDITIONS AND EXTERNAL LOADS

In the early phase of this analysis the loading on the Inlet Housing consisted solely of internal pressure within the torus. The pressure used (178 psid) was a nominal pressure supplied by engineers at the Huntsville Engineering Center (HEC). A package containing more realistic loads for the Inlet Housing, prepared by J. Chaffin of Rocketdyne (Ref. 2), was received by HEC and forwarded to LMSC, Sunnyvale, the week of 22 July 1988. Figure 12 is a schematic diagram of the FPL loading which was used for this final analysis. As can be seen in the figure, the 178 psid was increased to 303 psid. The maximum value for these loads in a surge condition is not conclusively known. For the purpose of this analysis, a 10% alternating pressure component was assumed.

The boundary conditions for the global model were simply a fixity of all translations at the location where the Inlet Housing is bolted to the main body of the pump. The support structure (to which the Hydrogen Inlet Manifold is bolted) was not restrained in any way.

The loading on the detailed vane submodel consisted of applied displacements along the boundaries of the submodel and pressure loads, to match the values depicted in Figure 12 for the global model (303 psi internal pressure and 208 psi external back pressure). The applied displacements were obtained from the global model through an automated process in the DIAL finite element code. Figure 13 shows the detailed vane submodel (the torus is removed for clarity) with the surfaces to which the displacement boundary conditions are applied. As can be seen from the figure, displacements were applied on each radial cut surface (at 24° and -30°) as well as on the two circumferential cut surfaces of the submodel. Since the circumferential cut surfaces lie directly behind the vane attachments, it is clear that the displacements applied to these surfaces will have, by far, the largest effect on the stresses in the vane and fillets. Figures 14a and 14b show the applied displacement vectors on either end of the submodel torus.

The displacements applied to the boundaries of the submodel were compared manually with the displacements of the global model (at the same locations) as a check on the automated process mentioned above. The displacements were continuous and smooth, and no discrepancies were found.

The submodel, which contains one vane, required a span of 54° to assure that there was sufficient distance between the ends of the vane and the model boundaries. However, since the Inlet Housing has 15 vanes around the circumference, the average span per vane is really 24°. This means that there is a significant overlap between the vanes which is not accounted for in the submodel (see phantom lines in Figure 13). The fact that the submodel does not include the portions of the other vanes that would exist in a 54° segment does not significantly affect the accuracy of the results, though. The reason for this is that the applied displacements (which completely dominate the loading) are obtained from the global model, in which there is a vane every 24°. If the displacements are correct, then the loading into the vane should be correct.

One effect of the larger span is an increased surface area for the applied pressure to act upon. The increase in vane stresses due to this additional pressure load is very small because the applied displacements are the major contributor to the stresses in the vane.

4. MATERIAL PROPERTIES

The material used for the HPFTP Inlet Housing is Ti-5Al-2.5Sn ELI. All material property information was obtained from the Rocketdyne Materials Properties Manual (Ref. 3) for a temperature of -350 °F. Figures 15 through 18 show excerpts from the Rocketdyne manual for a stress/strain curve (typical values are shown), a high-cycle fatigue S/N curve, a Modified Goodman Diagram (for a machined surface), and a low-cycle fatigue diagram.

5. STRUCTURAL ANALYSIS

Several iterations were made to improve and validate both the 360° global model and the detailed vane submodel. These iterations are documented in detail in prior Progress Reports and therefore will not be discussed here.

5.1 APPROACH

At the onset of this analysis, it was determined that two models (a 360° global model of the entire Inlet Housing and a detailed submodel of a single vane) would be necessary to adequately assess this geometrically complex part. The global model served three purposes:

- Prediction of the location of the highest vane stresses
- Displacement boundary conditions for the detailed vane submodel analysis
- A first order prediction of stresses in the critical weld areas where the torus is attached to the Inlet Housing main body.

The purpose of the detailed vane submodel was to achieve accurate modeling of the critical weld areas and a vane (complete with fillets). Both of these models were needed to assess the capability of this part to withstand the required environment.

5.2 RESULTS

5.2.1 Global Model

The primary purpose of the global model was to provide displacement boundary conditions for the detailed vane submodel. The stresses are not considered to be accurate, but they are presented here for completeness.

Figure 19 is an effective stress contour plot of the outer ring (from inside the ring looking out) due to FPL loading. Note that there is clearly a region where the stress appears to be the greatest. This maximum (~ 90 ksi) occurs at the location where the torus diameter is a maximum (near vane 1). This is logical, when one considers that the stress in a cylinder with internal pressure varies in direct proportion with the radius of that cylinder. Figure 20 shows the effective stress in the inner ring (from outside the ring looking in) at FPL. Note, again, that the stress varies along the circumference, with the maximum (85 ksi) occurring at the maximum torus diameter location. The weld area on the inner ring (weld 1) is indicated by the dashed line. Because this weld is smooth, with no stress concentrations, the stress here is only about 55 ksi. Figure 21 shows the computed effective strain in vane 1 (at the maximum torus diameter). This also varies as a function of circumferential position.

5.2.2 Detailed Vane Submodel

Based on the results of the global model, the vane closest to the torus maximum diameter was selected to be modeled in the detailed vane submodel. Figure 22 is a color contour plot of the inside (where pressure is applied) surfaces of both the inner and outer rings and the vane. The areas of particularly high stress are clearly shown to be the fillets of the vane and the weld 2 (outer ring) area. Figures 23 and 24 show line contour plots of the effective stresses (for FPL loading) on the inner ring non-pressure and pressure surfaces, respectively. Figure 25 shows the same for the outer ring pressure (inside) surface. The maximum value for effective stress in the inner ring is 119 ksi (Figure 23), and in the weld 1 area (Figure 24) it becomes ~ 90 ksi. The maximum effective stress in the outer ring occurs in the weld 2 area and peaks at a value of ~ 160 ksi. Please note that the areas near the boundaries where there appear to be extremely high stresses are of no concern. These high stresses are products of the applied displacements and die out very quickly.

Figure 26 shows the effective stress in the vane submodel (the torus is removed for clarity) at FPL loading. The maximum effective stress of 237 ksi occurs in the fillets at the leading edge of the vane. This stress value, which exceeds the ultimate stress capability of the material (Sy = 154 ksi, Su = 163 ksi - see Figure 15), is not accurate since it was computed assuming linear elastic material response. Figure 26 shows that the maximum effective strain for this linear analysis is 1.37%. The ultimate elongation for the material, according to the Rocketdyne Materials Properties Manual (Ref. 3), is on the order of 15%. The yielding in the vane fillet is extremely localized in the high stress concentration area of the fillet region. In reality (or in a nonlinear analysis), any yielding will allow the load to redistribute and therefore keep the plastic strain low and the margin of safety for the static load condition fairly high. There is little doubt, however, that the stresses in the vane fillet at FPL loading are at or above yield. This directly affects the fatigue life of the HPFTP Inlet Housing.

The current assumption with regard to fatigue life assessment is that the alternating load is 10% of the mean loading. Using this assumption, and looking at the Modified Goodman Diagram in Figure 17, it is clear that the weld 1 area (effective stress is 90 ksi) should withstand 10,000,000 cycles of loading. It is equally clear that the fatigue life of the HPFTP Inlet Housing vanes (effective stress, 237 ksi) and of the weld 2 area (effective stress, 160 ksi) will be extremely limited, possibly to the point of creating low-cycle fatigue problems. Since fatigue failures in the vanes are not common, the cyclic loading environment is apparently not nearly as severe as was assumed here.

6. SUMMARY

Table 2 is a summary of the results, for nominal and FPL loading, for both of the models used in this analysis. Overall, the effective stresses in the detailed vane submodel are about 40 to 78% higher than those predicted in the global model. This is most likely due to the coarseness of the 3-D global model mesh (which also used linear instead of parabolic solid elements). Note that a direct comparison of the stresses between the two models should not be made, since the global model's purpose was primarily to provide input for the detailed vane submodel. A comparison of average effective stress was made near the center of the critical vane for both models. The correlation here for the FPL loading is fairly good.

Table 2 HPFTP Inlet Housing Stress Analysis - Summary of Results

Model (load case)	Weld 1 Inner Ring	Weld 2 Outer Ring	Vane Fillet	Center of Vane 1
Global (NPL) Eff-Stress (ksi)	32	53	--	~20
Global (FPL) Eff-Stress (ksi)	55	90	--	~30
Detailed Vane (NPL) Eff-Stress (ksi)	53 (+1.9)!	94 (+.64)	--	~20
Detailed Vane (FPL) Eff-Stress (ksi)	90 (+.71)	160 (-0.04)*	237 (-.35)*	~30

NOTES: NPL - Nominal Pressure Level - 189 psid internal torus pressure.
FPL - Full Power Level - 303 psid internal torus pressure.
! - Numbers in parentheses are Static Margins of Safety based on a 1.0 Factor of Safety and Sy = 154 ksi.
* - These margins are the result of a linear analysis. A non-linear plastic analysis would most likely produce positive margins based on the maximum strain allowable of 15% (237 ksi corresponds to effective strain of 1.37%).

Static margins of safety for the FPL loading, based on a 1.0 Factor of Safety and a yield stress of 154 ksi, are included where the stress remains in the linear range. In the fillets of the vanes, where yielding occurs, only a nonlinear plastic analysis can provide a reliable margin.

An accurate assessment of the fatigue life of the HPFTP Inlet Housing requires a knowledge of the cyclic loading environment (including both magnitude and period of the loading), as well as an S/N curve and Modified Goodman Diagram for the proper material with the proper surface finish. Given the magnitude of the stresses predicted here, a low-cycle fatigue curve (for the proper R of +0.90) would also be helpful. Since these data do not yet exist, or at least they have not yet been provided, all that can be stated conclusively is that a concern for the fatigue life of this part does exist.

7. RECOMMENDATIONS

If it is true, as the results of this analysis show, that the vane fillets are stressed to nearly 1.5 times the stress level in the welds, then one must ask why there have been cracks reported in the welds but not in the fillets of the vanes. Apparently, either the material properties in the weld are very different from the wrought material in the vanes, or there is some aspect of the loading that is not being treated properly. Several missing pieces of information are essential to the closure of this study:

1. Material data for the weld material are needed in the form of a stress-strain curve, an S/N curve, a Modified Goodman Diagram for the proper heat-treat (annealed?), temperature (-350 °F), and surface conditions (chem milled?). The titanium in the weld material is a "cast" microstructure as opposed to a "wrought" microstructure for the vanes. Consequently, it is very possible, even likely, that their fatigue characteristics would be very different.

2. Measure pressure data are needed to verify the cyclic component of the load. The loading environment given for this problem assumes that the cyclic component of the load is 10% of the mean value. If it can be shown to be significantly smaller than this in the vane fillet, the loading can be regarded as static and the life of the vane fillet would be determined by low-cycle fatigue, where the number of cycles is the number of engine firings.

3. Data on the effect of cyclic loading with plastic prestrain are needed to predict the life of the vane fillet if the cyclic component of the loading is in fact significant.

4. A nonlinear plastic analysis is needed to determine the level of plastic strain in the vane fillet. This knowledge can be used to determine the static margin of safety and assess the low-cycle fatigue capability of the part, given the data in item 3 above.

8. REFERENCES

1. DIAL Finite Element Analysis System, User's Manual. LMSC Document.
2. J. Chaffin, Rocketdyne Internal Memo, 14 July 1988.
3. Rocketdyne Materials Properties Manual, Section 5002 (Ti-5Al-2.5Sn ELI).

ORIGINAL PAGE
COLOR PHOTOGRAPH

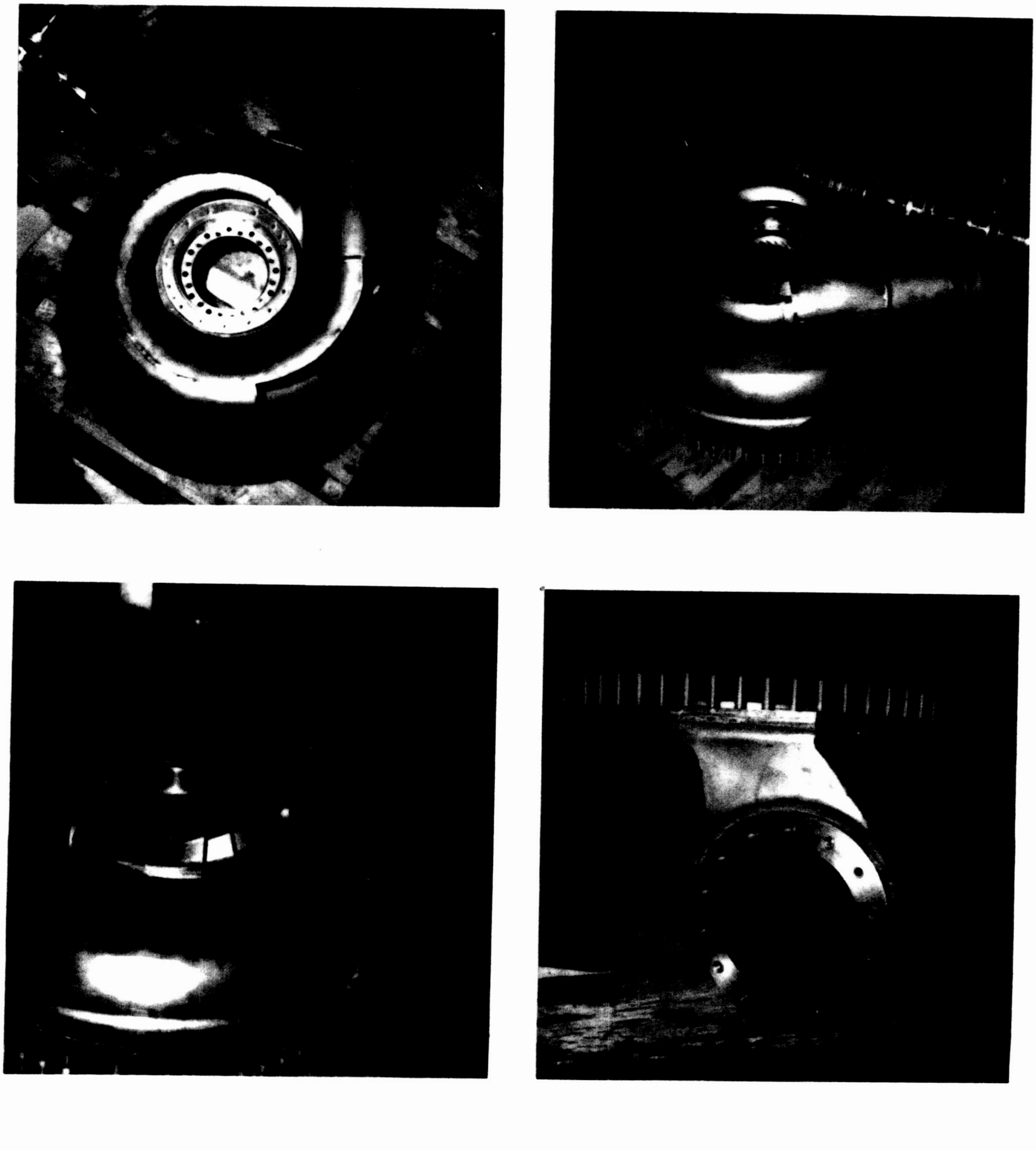


Figure 1 Polaroid Photographs of Cut-Up HPFTP Inlet Housing

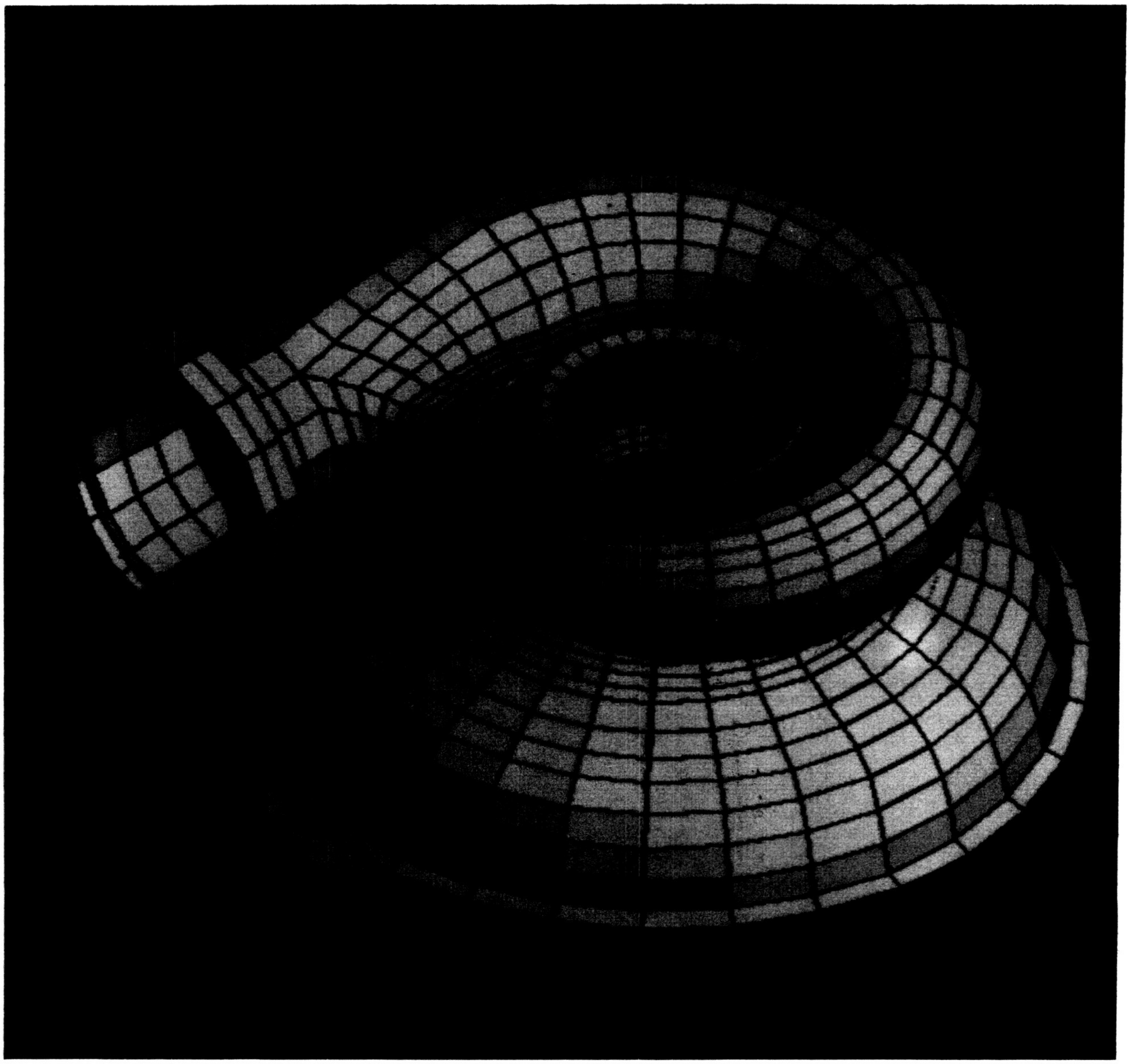


Figure 2 HPFTP Inlet Housing - DIAL Global Finite ELement Model

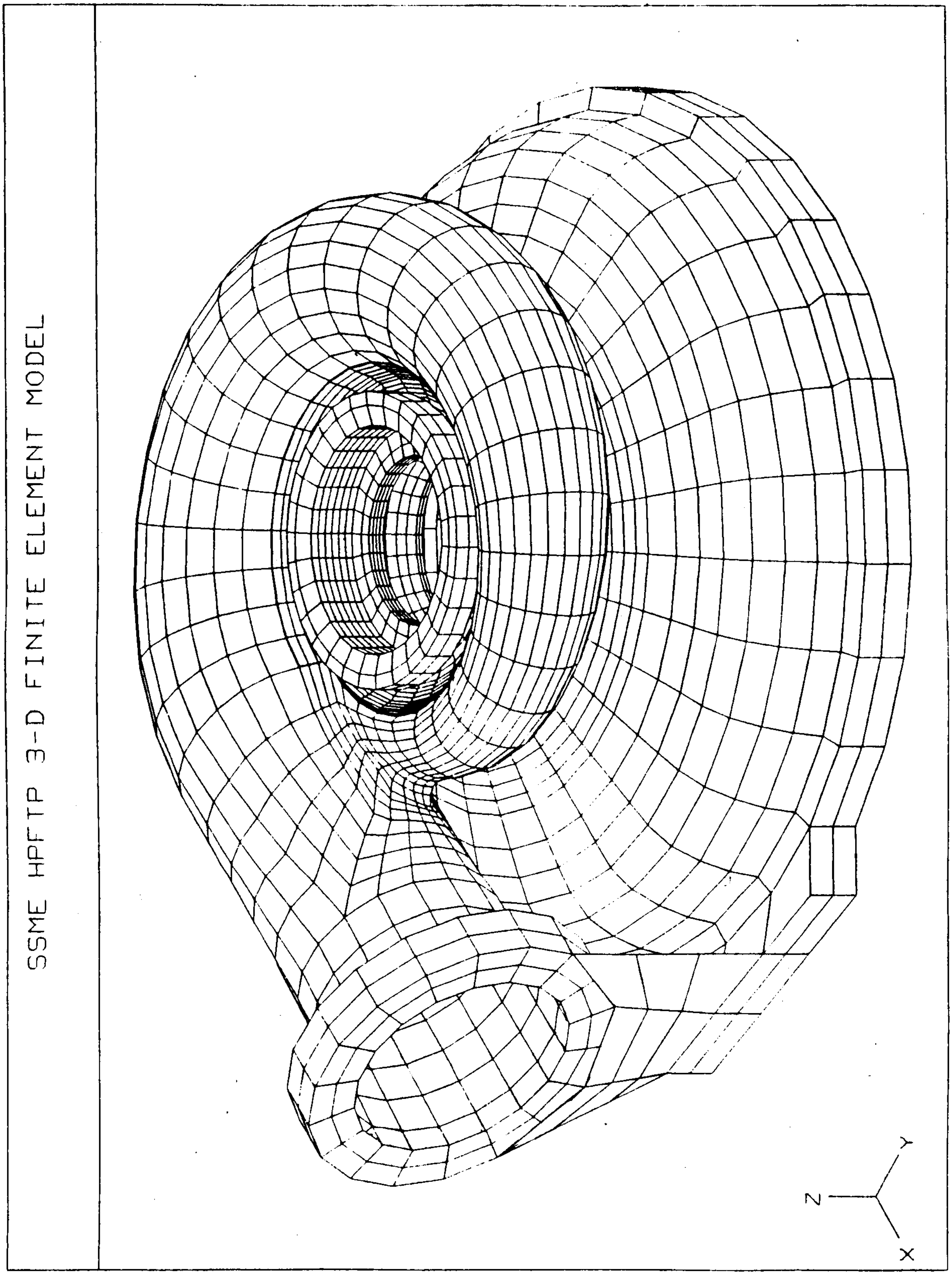


Figure 3 HPFTP Inlet Housing - DIAL Global Finite Element Model
(Looking from Pump Toward Turbine)

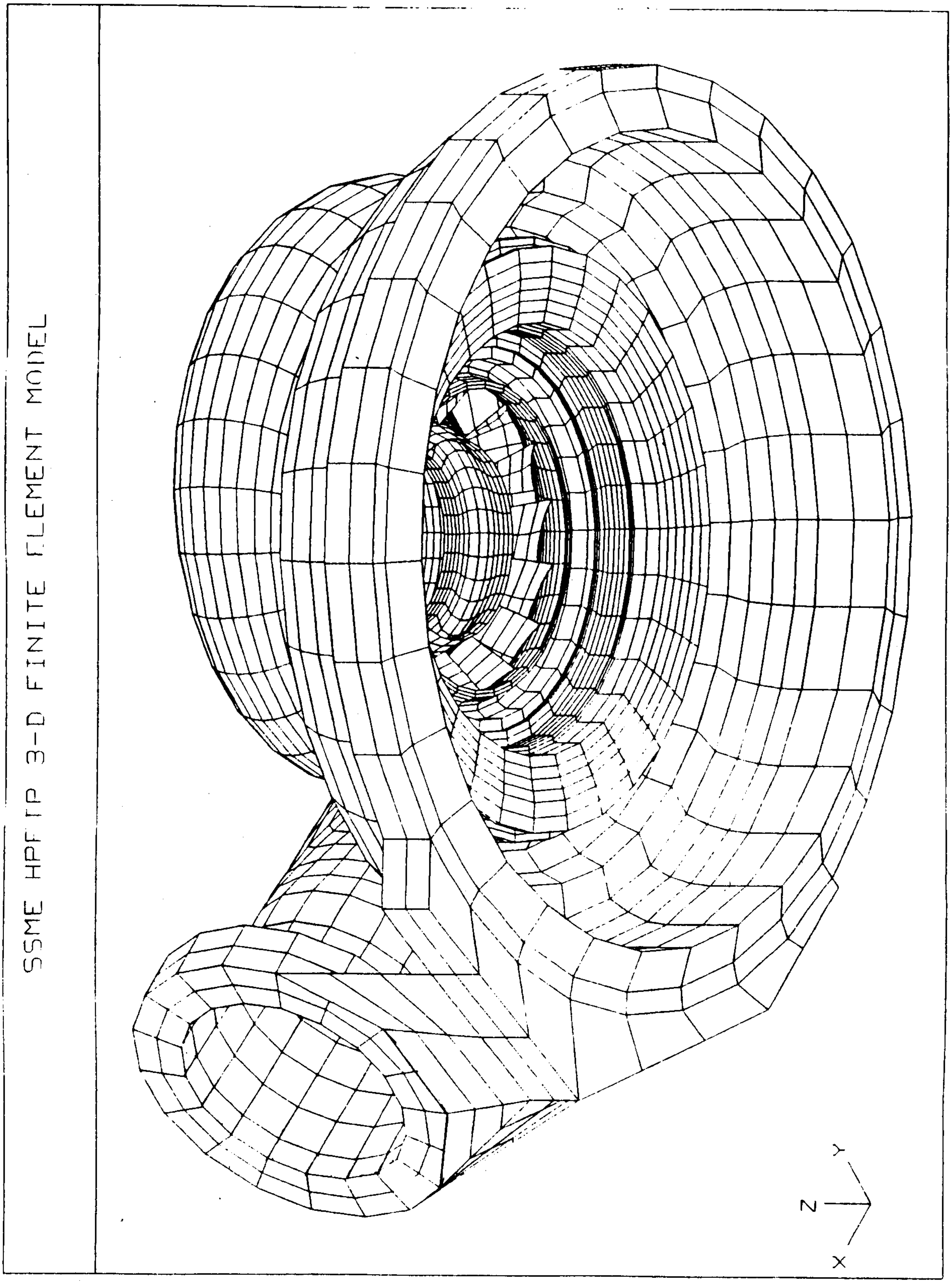


Figure 4 HPFTP Inlet Housing - DIAL Global Finite Element Model
(Looking from Turbine Toward Pump)

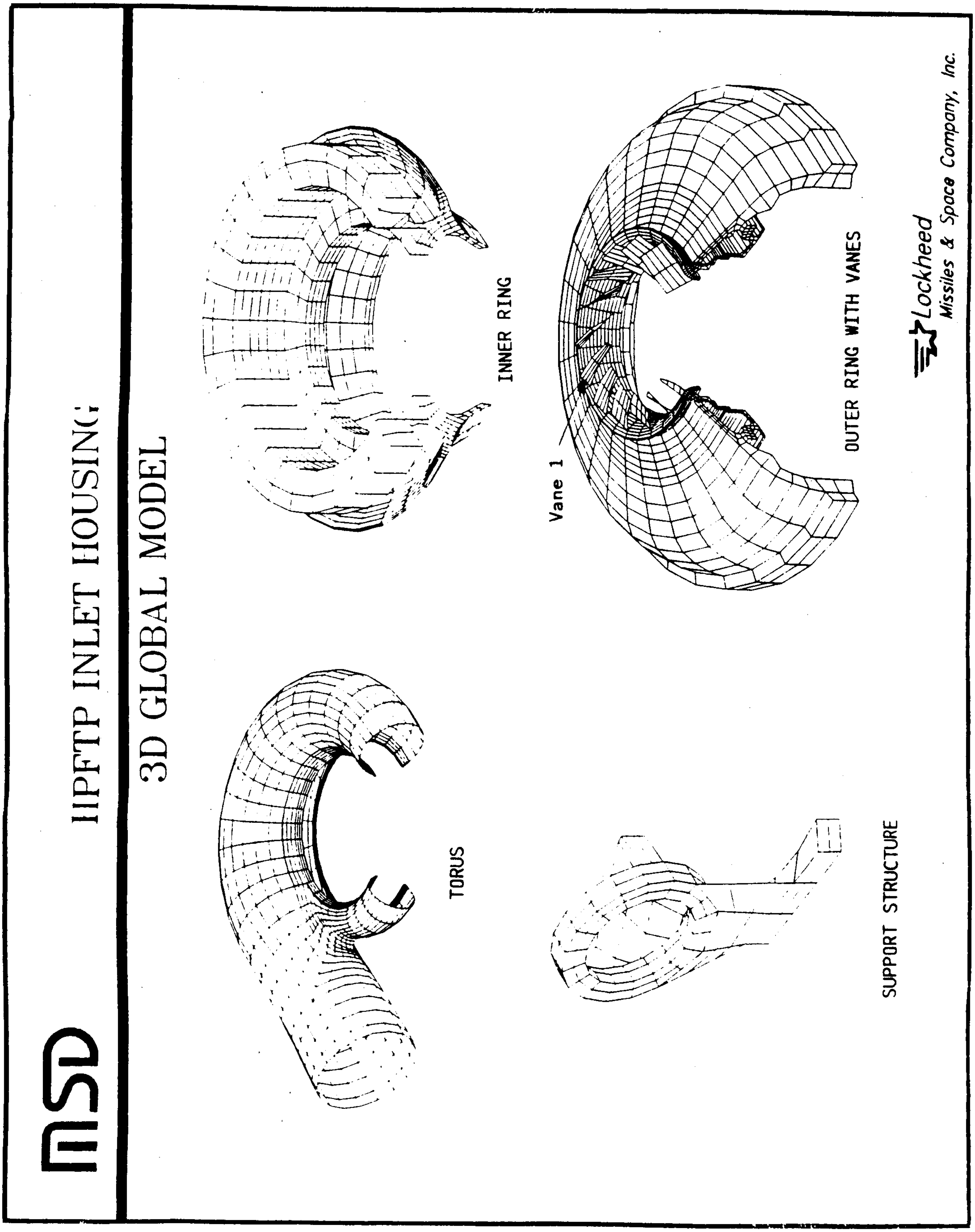


Figure 5 HPFTP Inlet Housing - DIAL Global Finite Element Model
Exploded View Showing Model Components

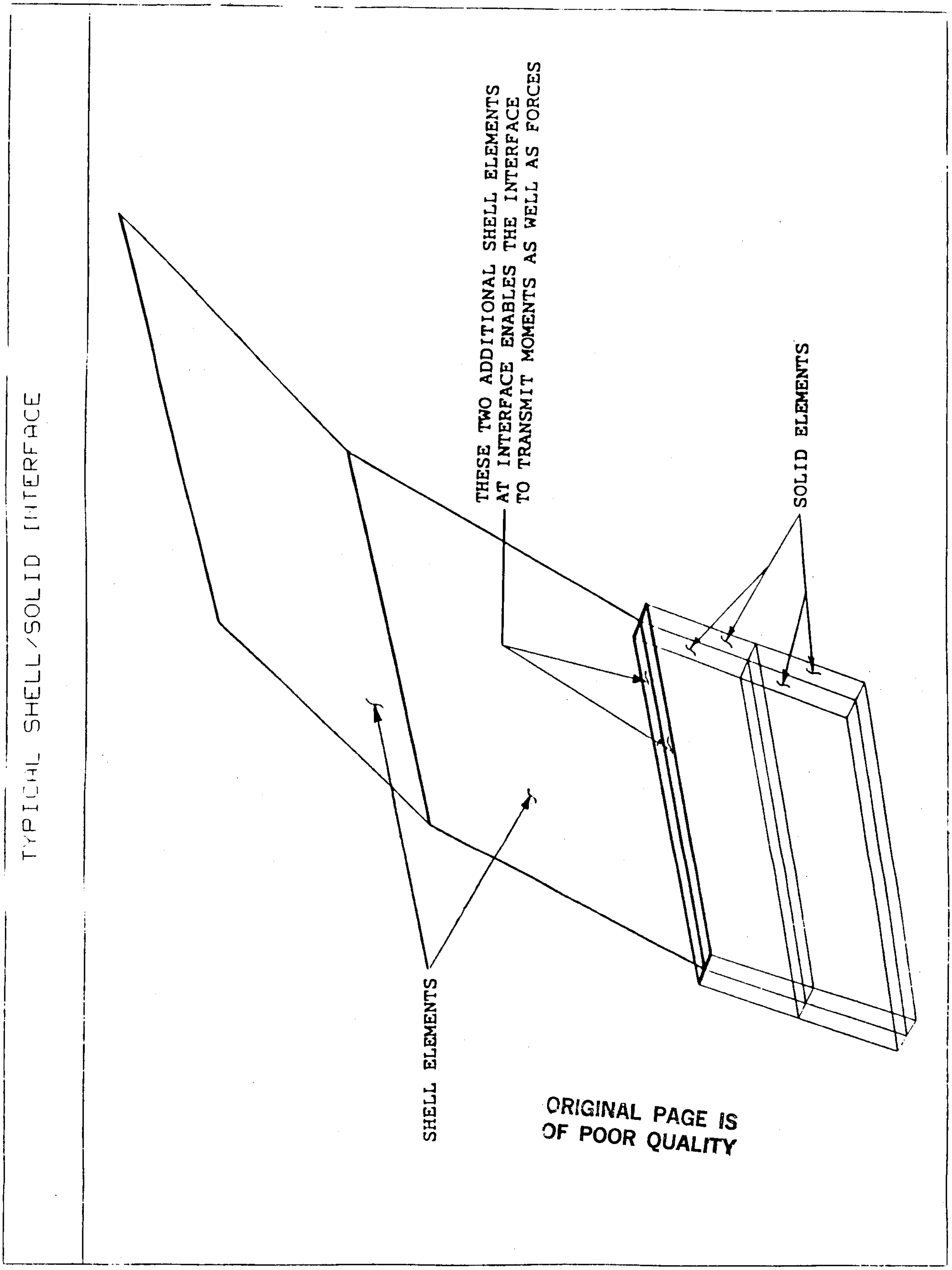


Figure 6 HPFTP Inlet Housing - DIAL Global Finite Element Model
Shell/Solid Element Interface (in Torus)

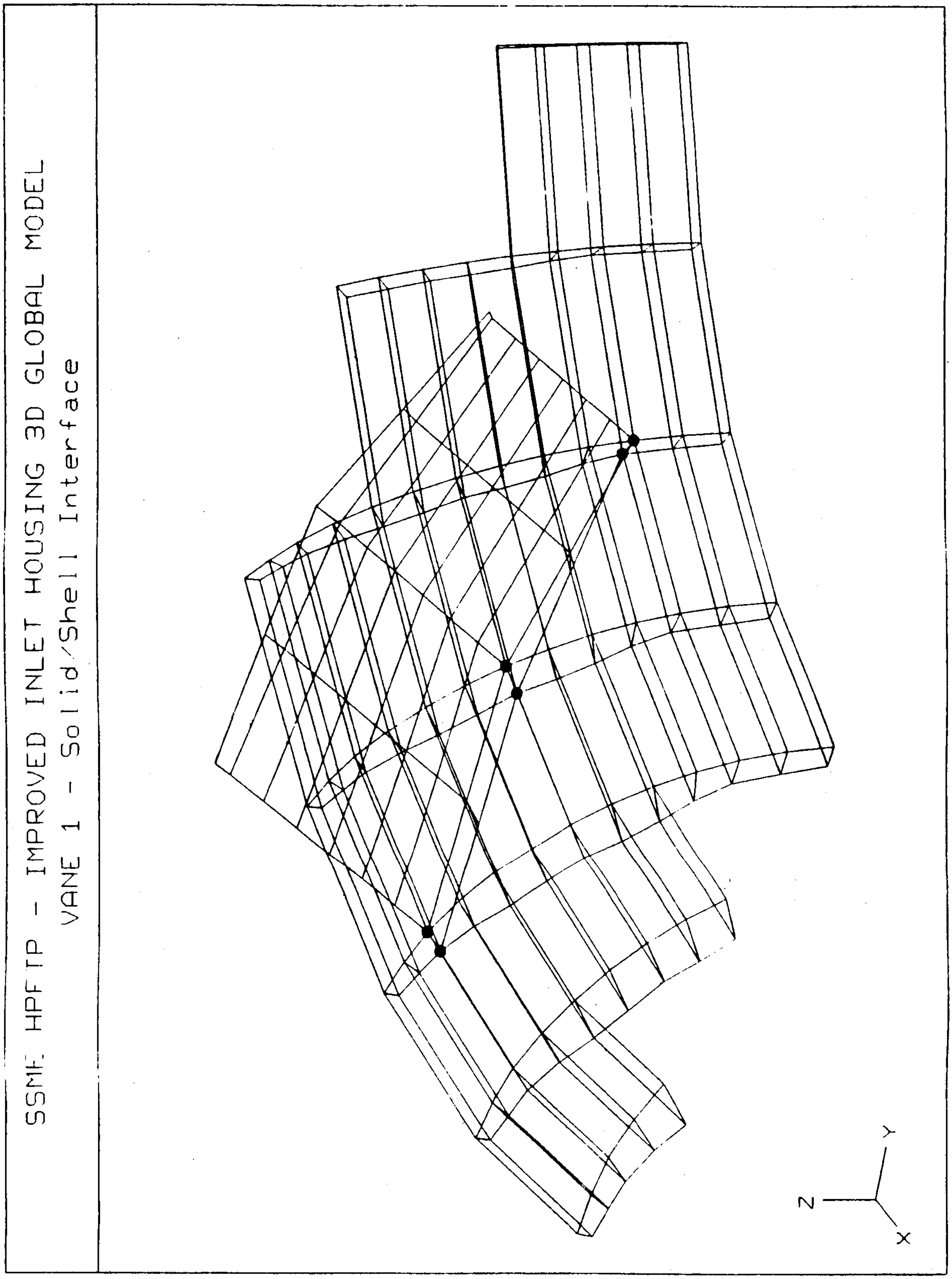


Figure 7 HPFTP Inlet Housing - DIAL Global Finite Element Model
Typical Shell Element Vane/Solid Element Connection

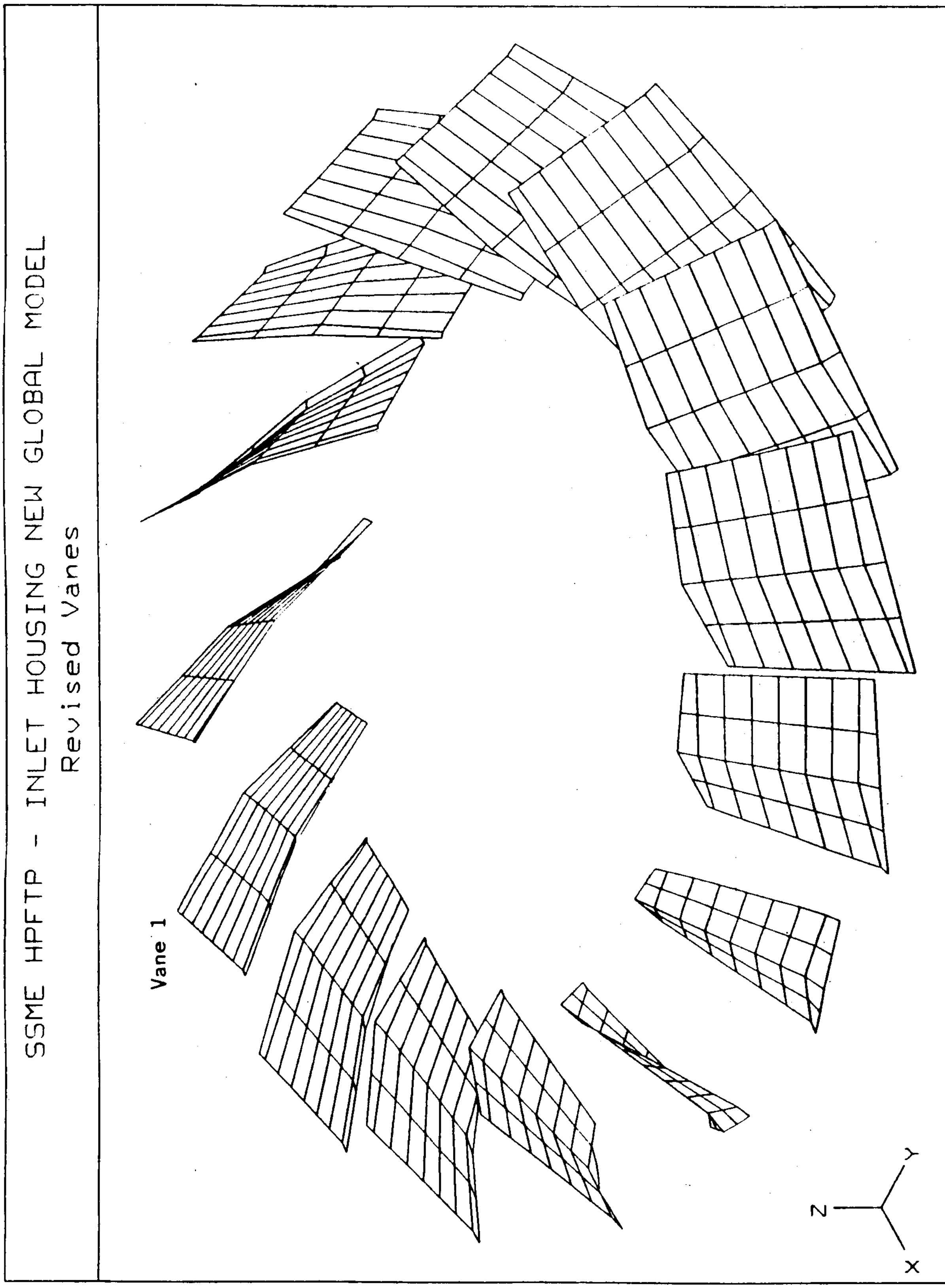
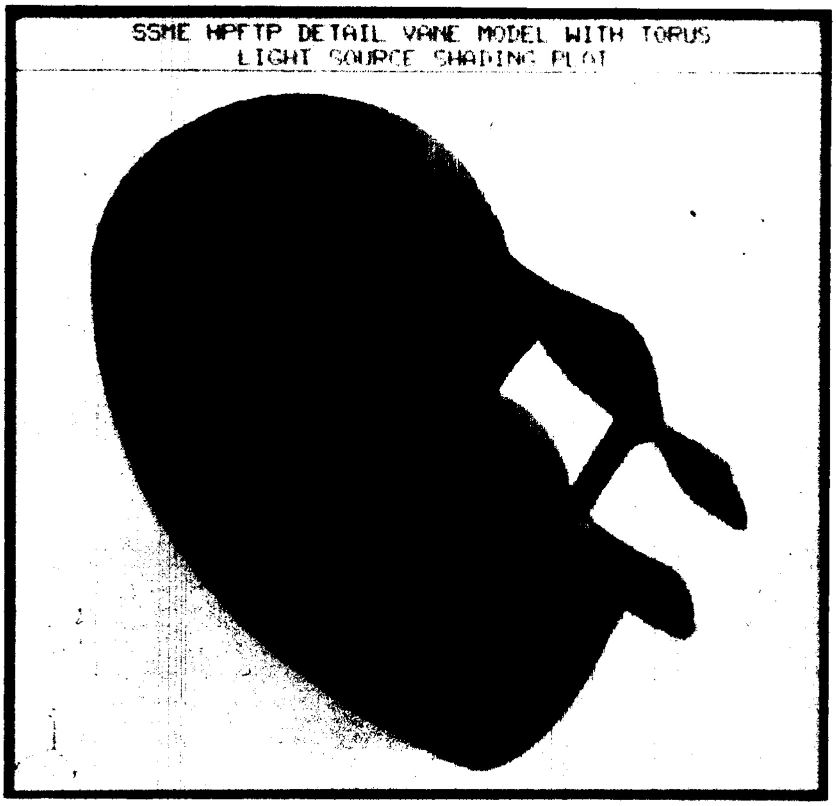


Figure 8 HPFTP Inlet Housing - DIAL Global Finite Element Model
Final Configuration of Shell Element Vanes



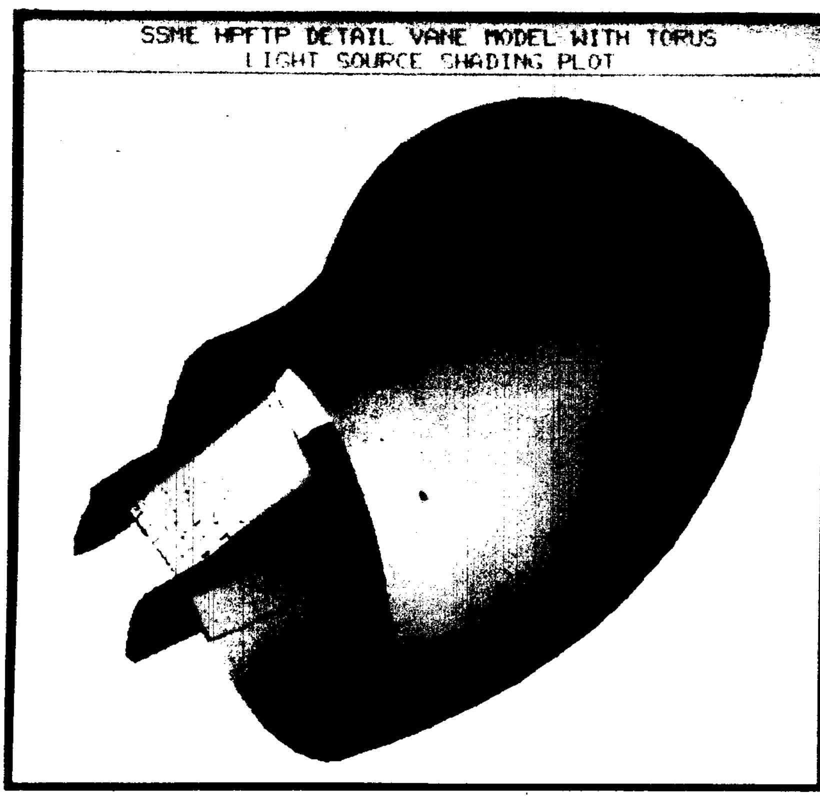


Figure 9(a,b) HPFTP Inlet Housing - DIAL Detailed Vane Submodel
(Color Light Source Shading Plot)

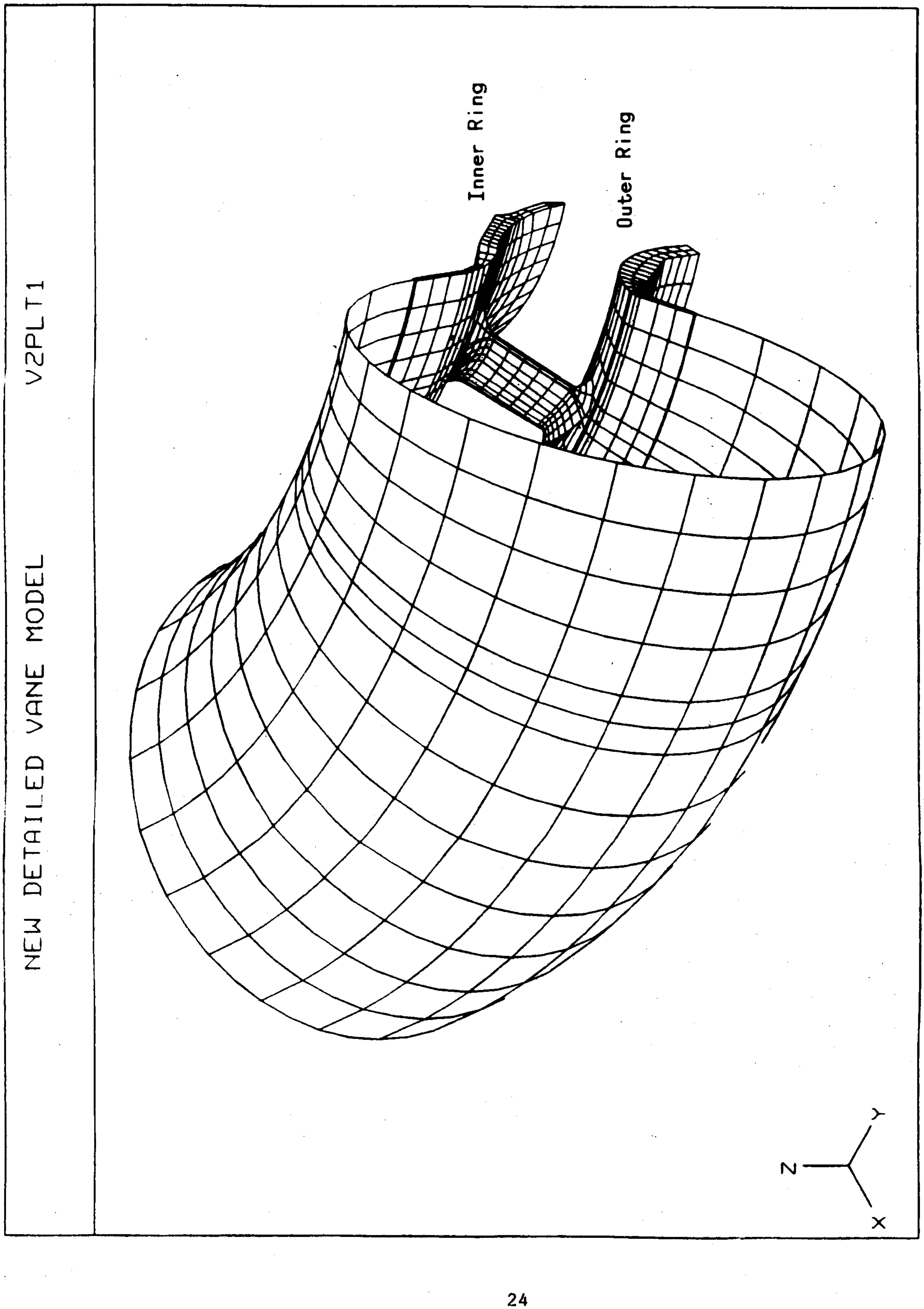


Figure 10 HPFTP Inlet Housing - DIAL Detailed Vane Submodel
(Looking from Larger End of Torus Toward Smaller End)

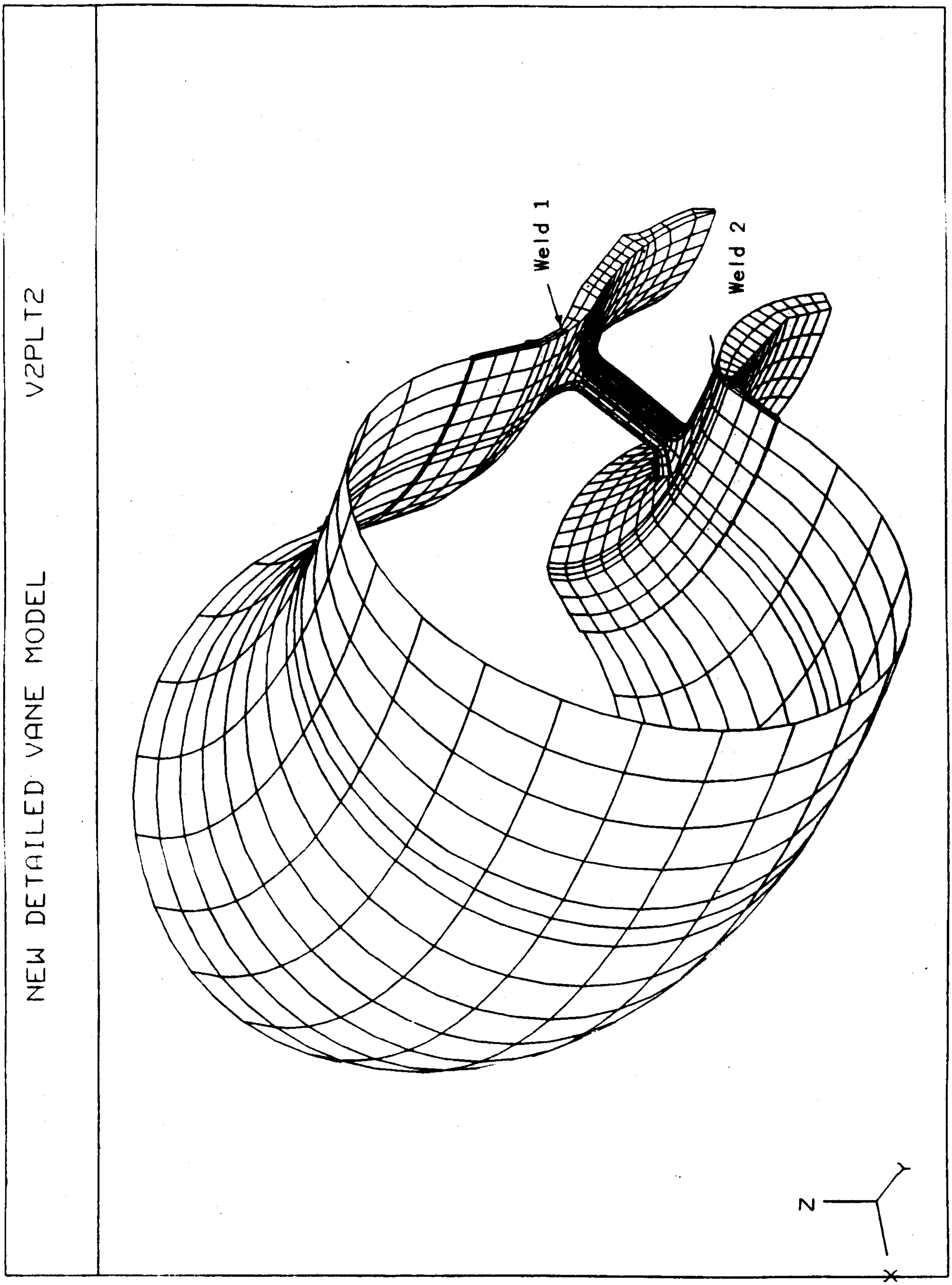


Figure 11 HPFTP Inlet Housing - DIAL Detailed Vane Submodel (Looking from Larger End of Torus Toward Smaller End)

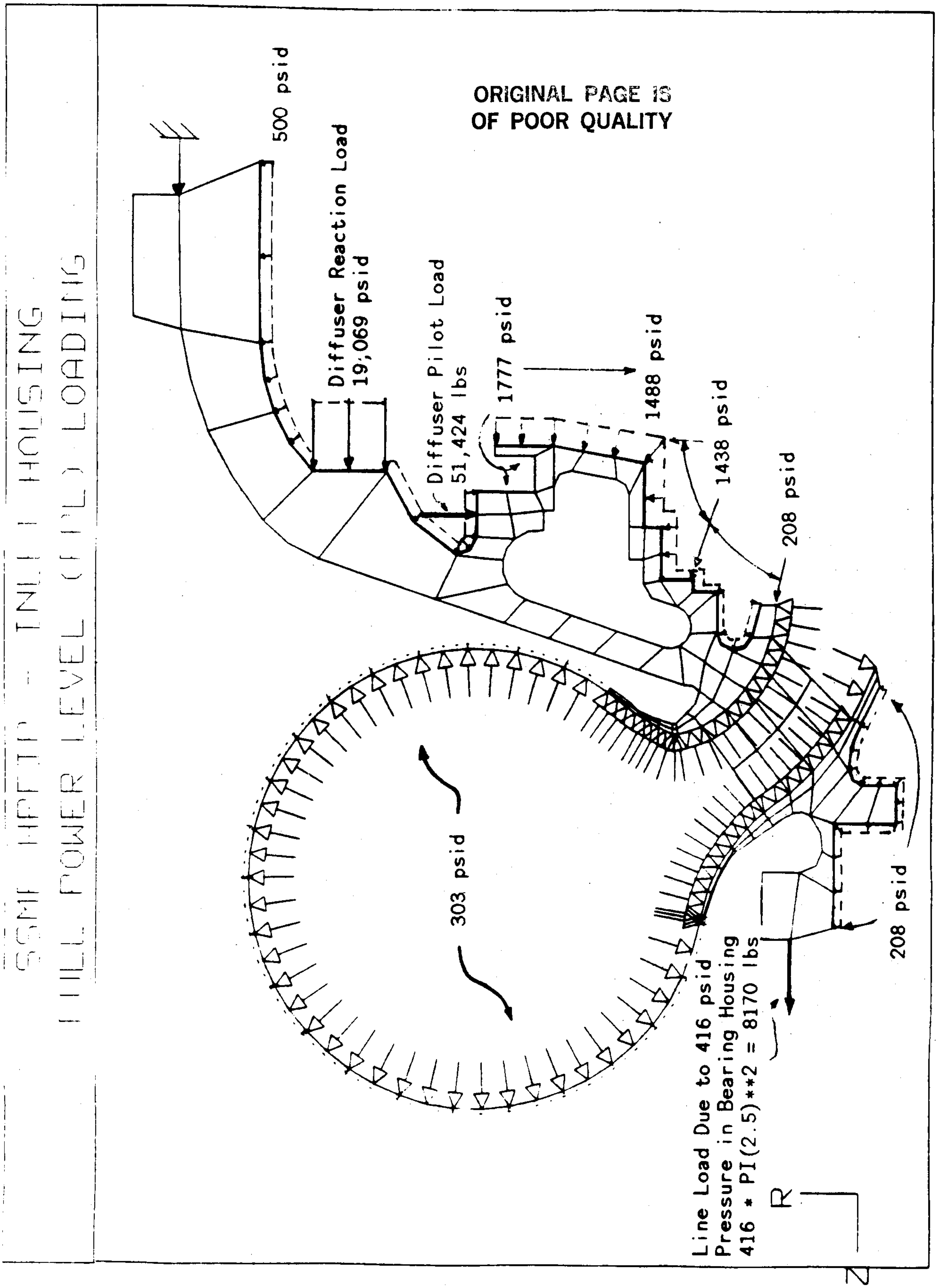


Figure 12 HPFTP Inlet Housing - Applied FPL Loading

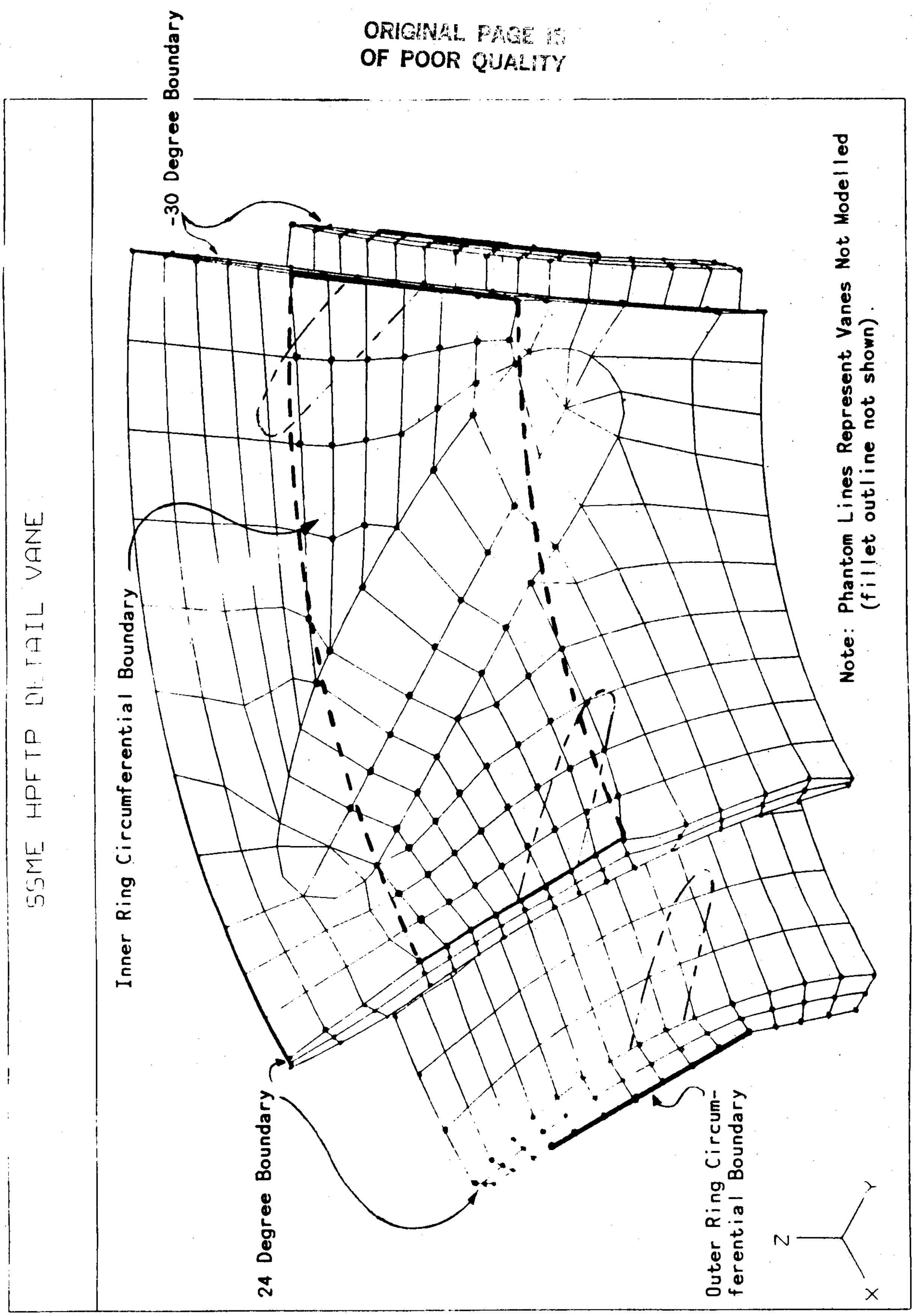
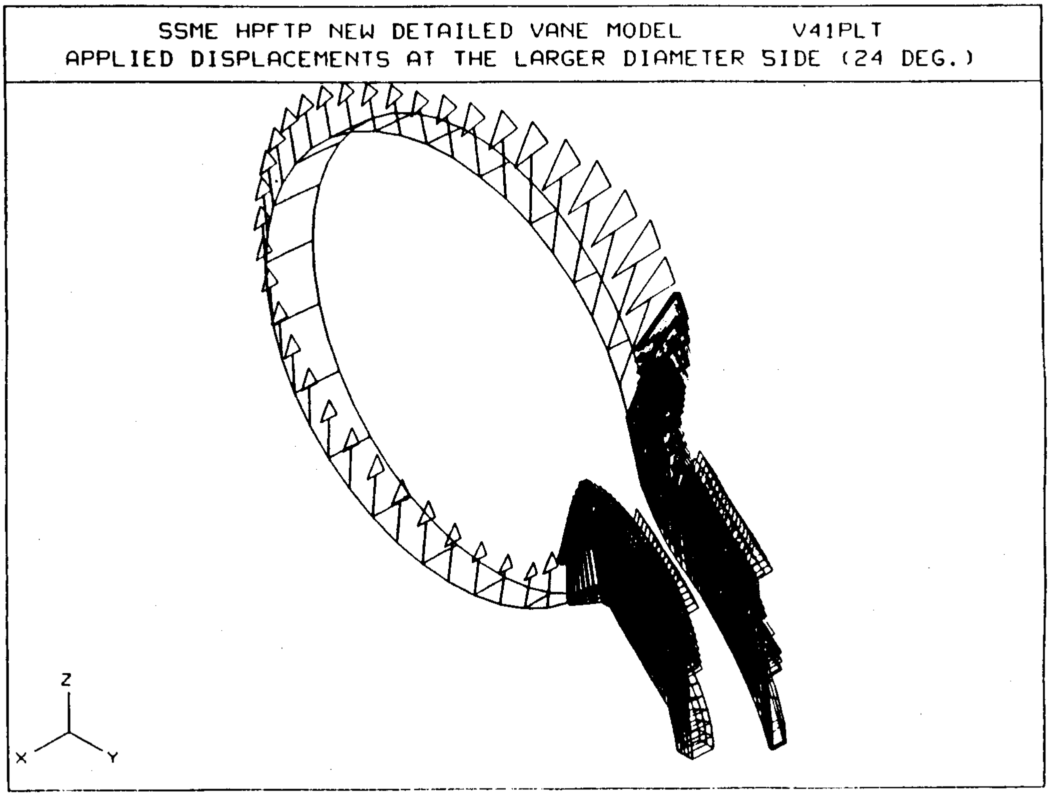


Figure 13 HPFTP Inlet Housing - DIAL Detailed Vane Submodel
Applied Displacement Boundaries (from Global Model)
(Torus Removed for Clarity)



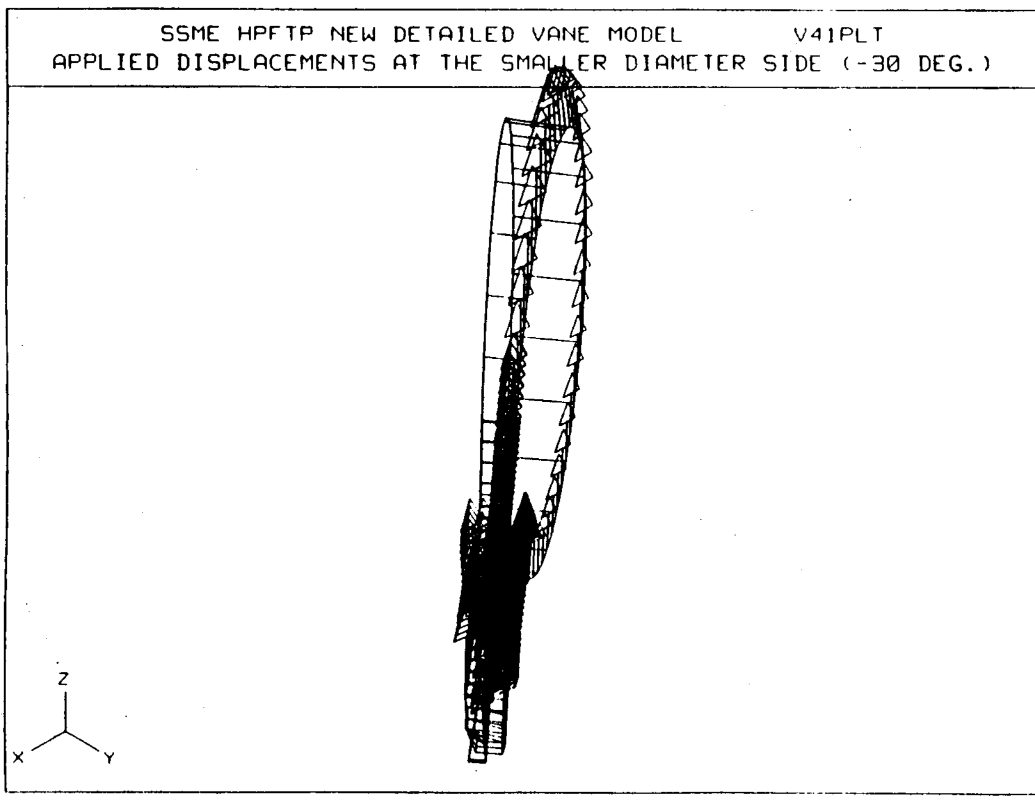


Figure 14(a,b) HPFTP Inlet Housing - DIAL Detailed Vane Submodel
Applied Displacement Vectors from Global Model (Torus)

ROCKWELL INTERNATIONAL
ROCKETDYNE DIVISION

MATERIALS PROPERTIES MANUAL

TYPICAL (PREDICTED)
1700F AIR 3HRS/1400F VACUUM 4HRS

DATE-07-07-87
REFERENCE-5002-09
3RD EDITION PAGE-5002.27.10.50-01

5002.27.10.50-01A

TI-5AL-2.5SN ELI
STRESS-STRAIN DIAGRAM
WROUGHT, CONVENTIONAL
ANNEALED

SPEC RB0170-079.152

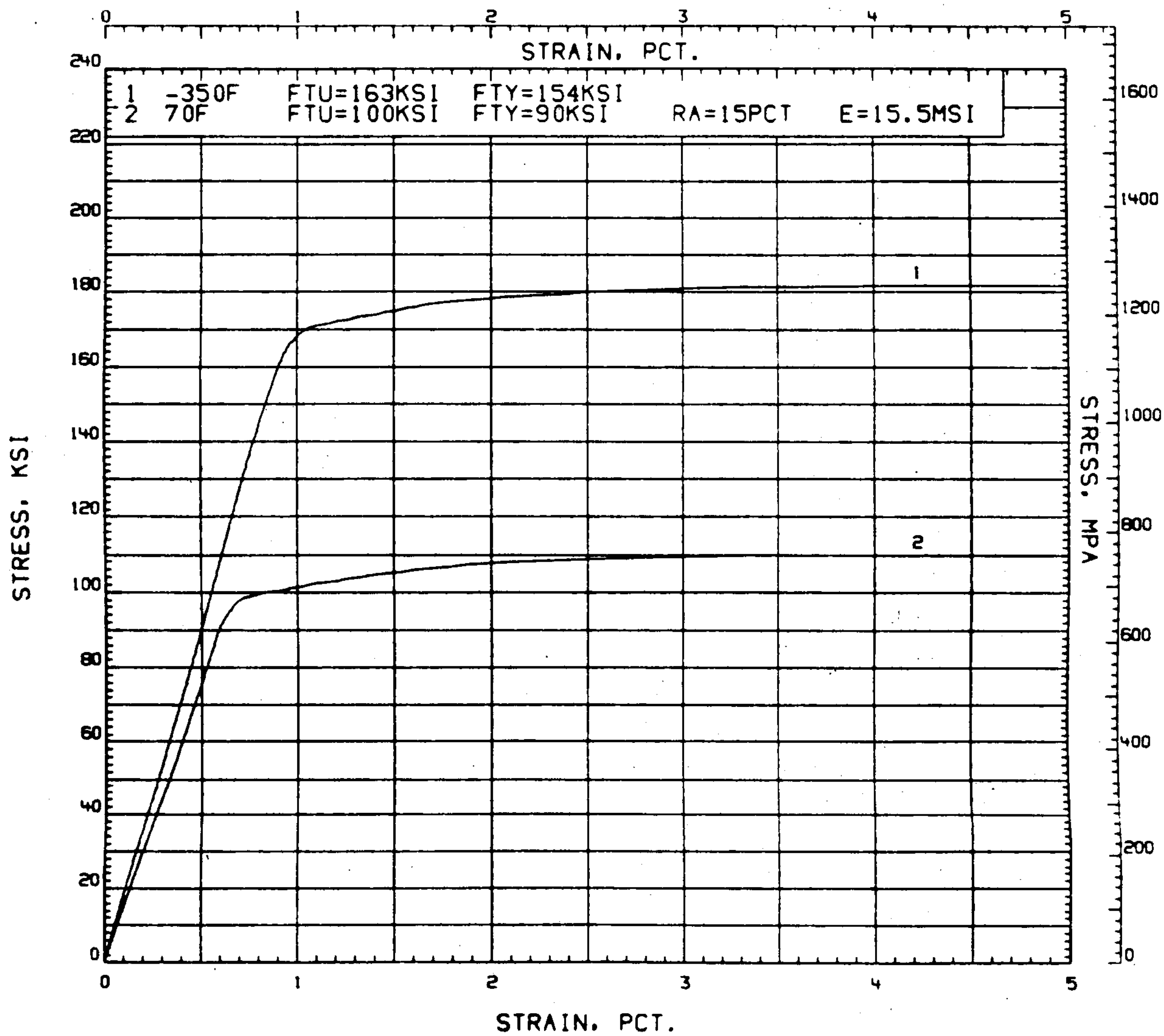


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Figure 15 Rocketdyne Materials Properties Manual - Ti-5Al-2.5Sn (ELI) Stress/Strain Curve (Typical Values)

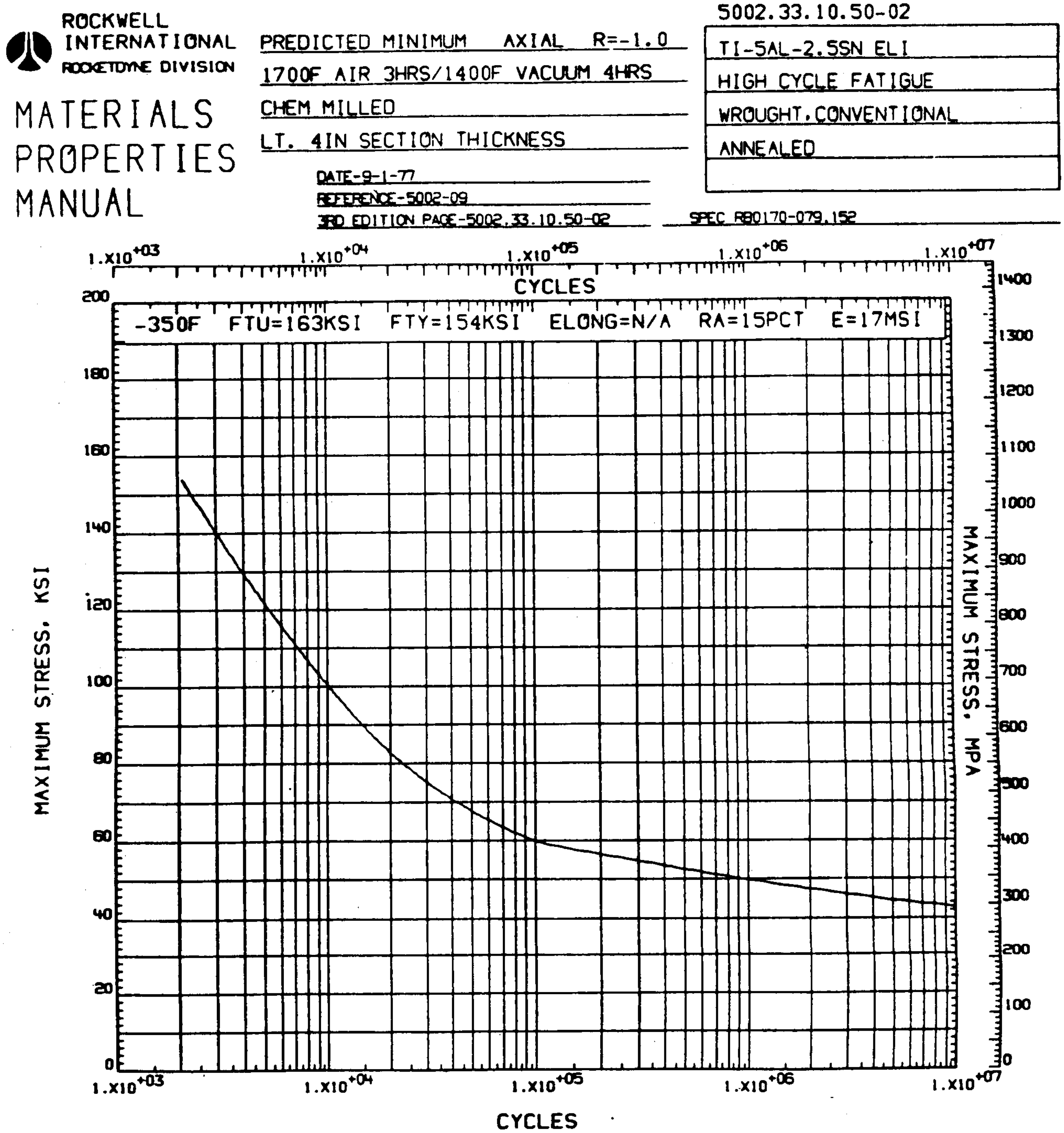

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Figure 16 Rocketdyne Materials Properties Manual - Ti-5Al-2.5Sn (ELI) Stress vs Number of Cycles to Failure (S/N) Curve (R = -1.0)

ROCKWELL INTERNATIONAL
ROCKETDYNE DIVISION

MATERIALS PROPERTIES MANUAL

5002.33A.12.50-02

EXPECTED MINIMUM	TI-5AL-2.5SN ELI
AXIAL	MODIFIED GOODMAN DIAGRAM
MACHINED 32 FINISH	BAR OR FORGING
1700F AIR 3HRS/1400F VACUUM 4HRS	ANNEALED

DATE-9-1-77
REFERENCE-5002-04 (MPR 9-176A-123)
3RD EDITION PAGE-5002.33.12.50-02
SPEC RB0170-079.152

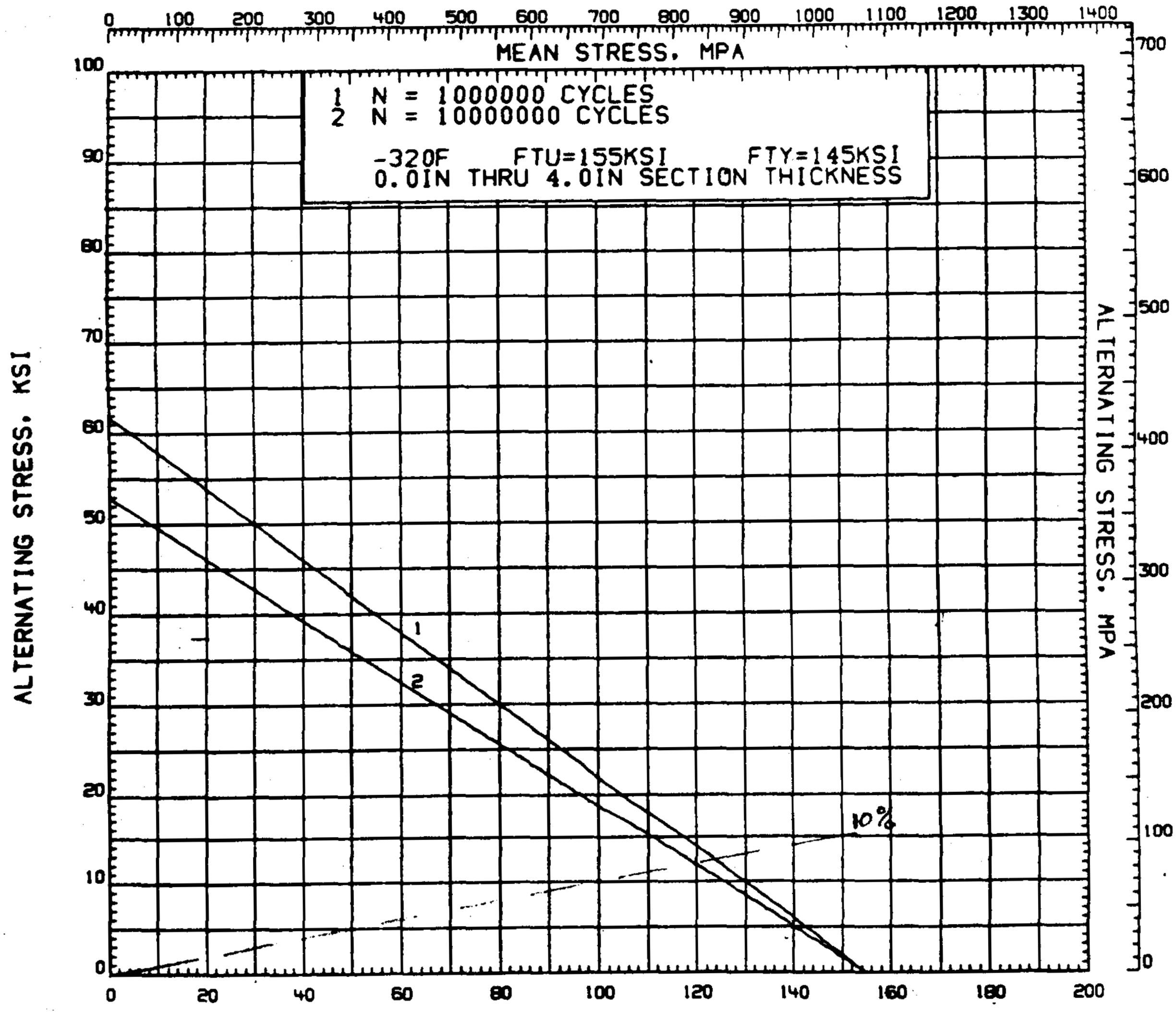

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Figure 17 Rocketdyne Materials Properties Manual - Ti-5Al-2.5Sn (ELI) Modified Goodman Diagram (Machined Surface Finish)

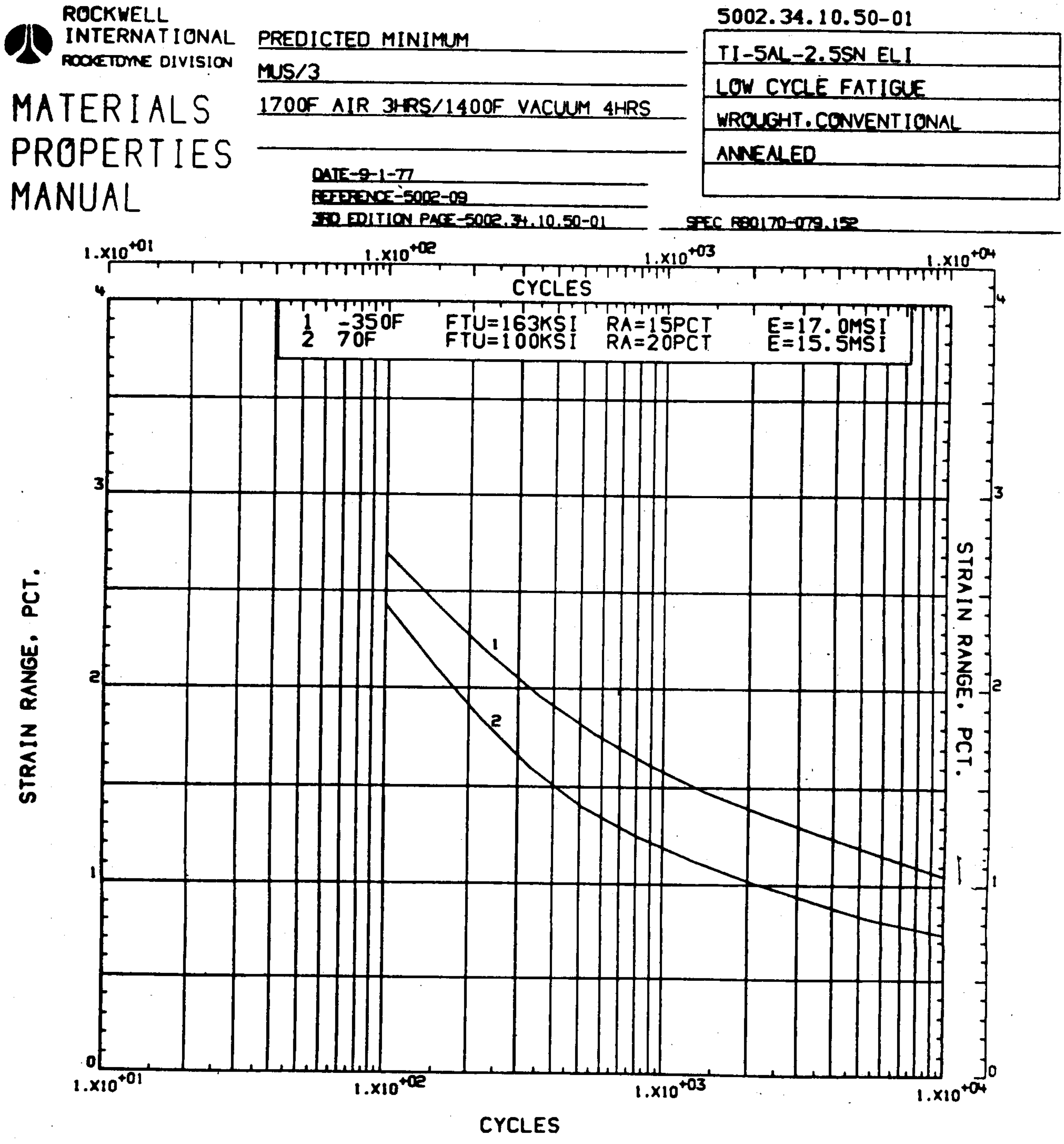

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Figure 18 Rocketdyne Materials Properties Manual - Ti-5Al-2.5Sn (ELI) Low Cycle Fatigue - Plastic Strain vs Number (R = -1.0))

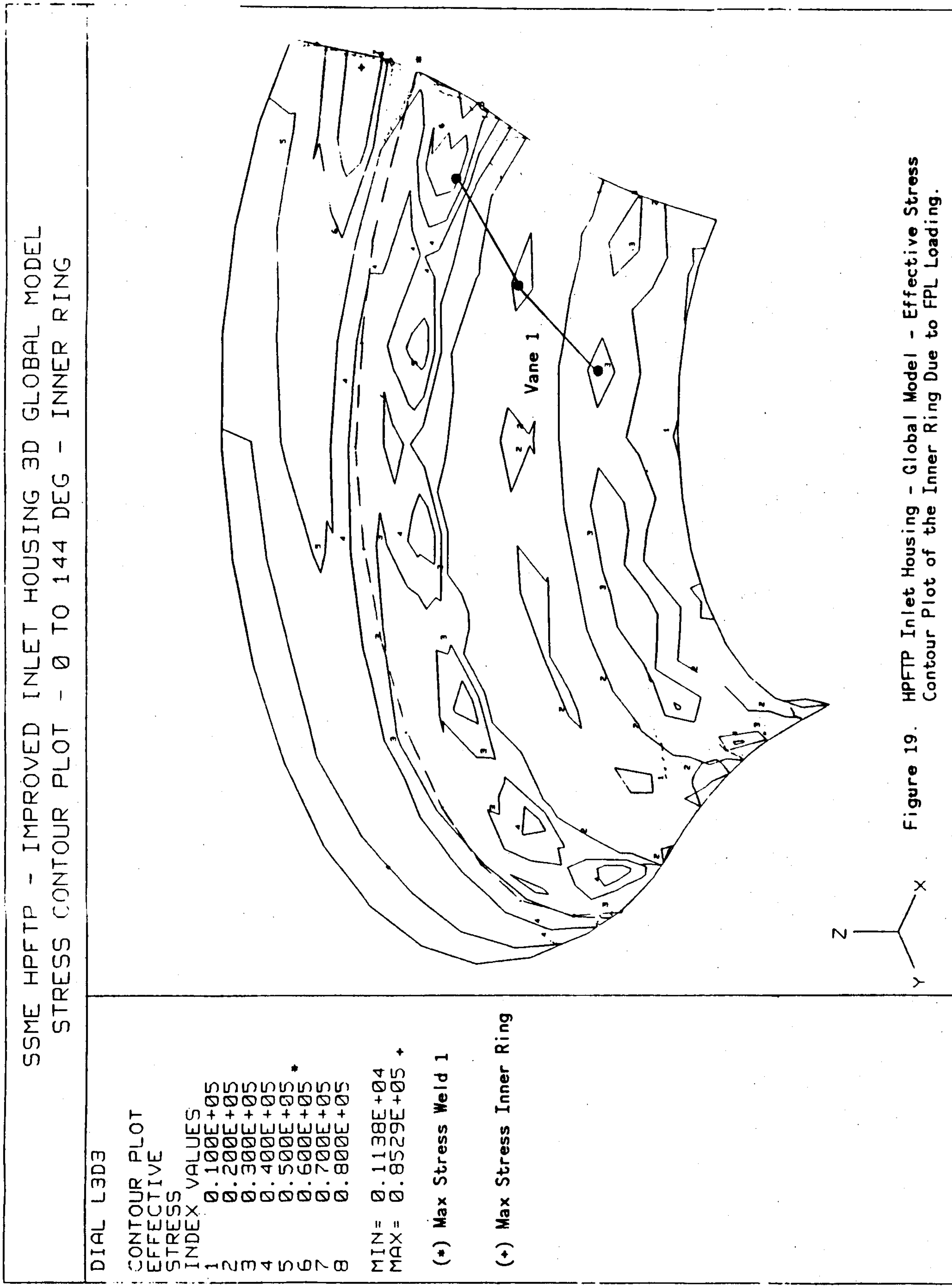


Figure 19 HPFTP Inlet Housing - Global Model - Effective Stress Contours Plot of the Inner Ring Due to FPL Loading

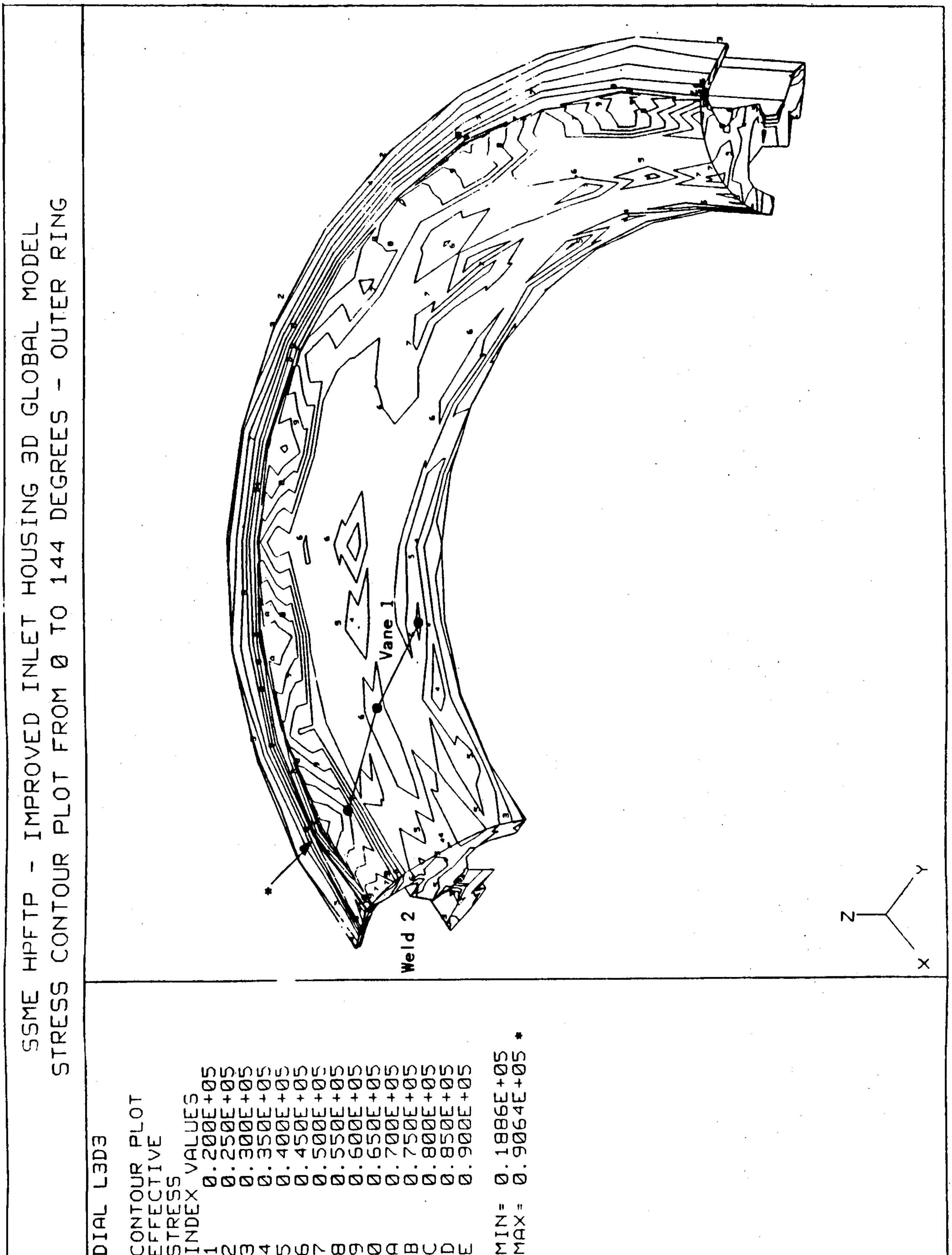


Figure 20 HPFTP Inlet Housing - Global Model - Effective Stress Contour Plot of the Outer Ring Due to FPL Loading

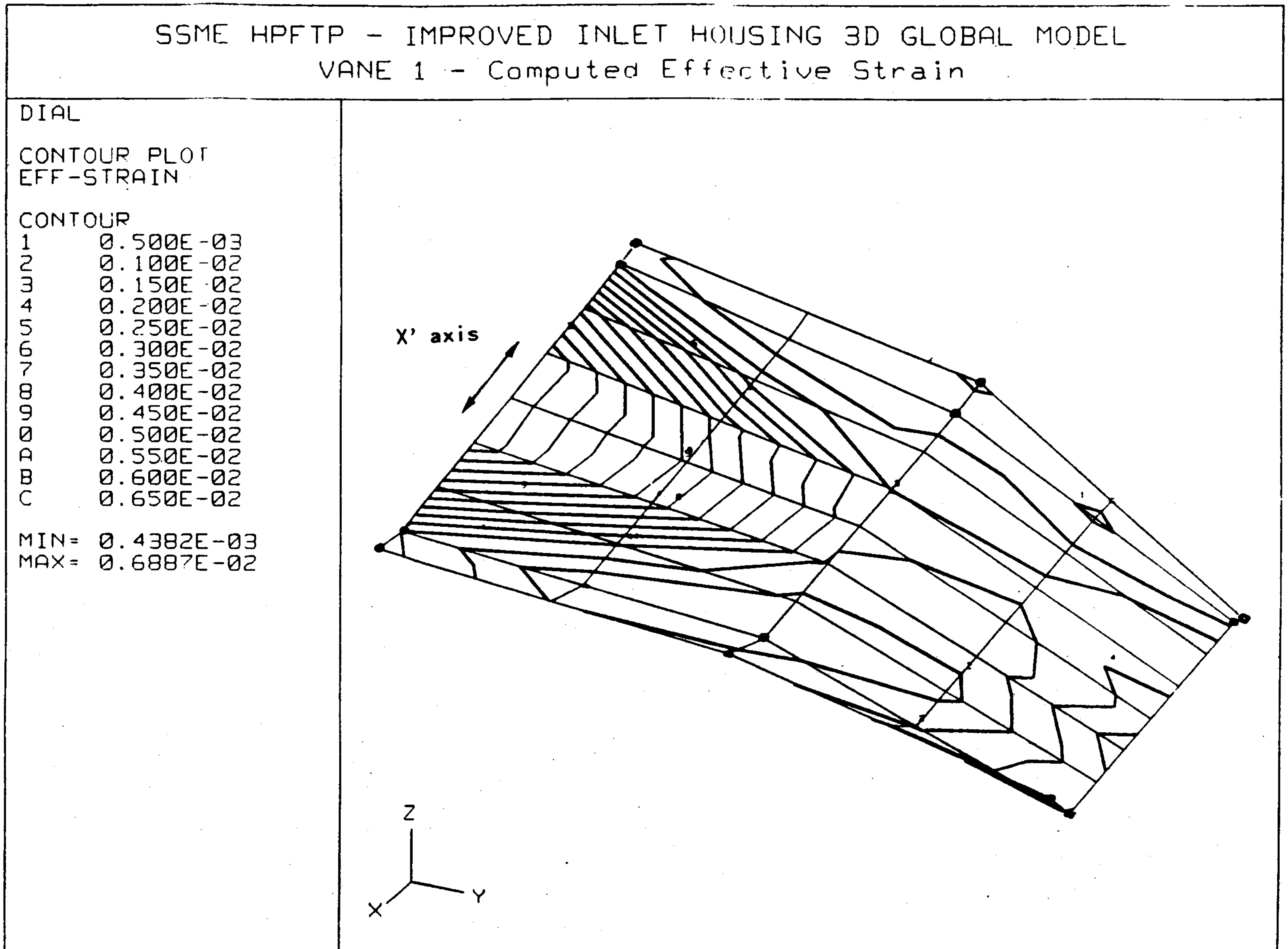
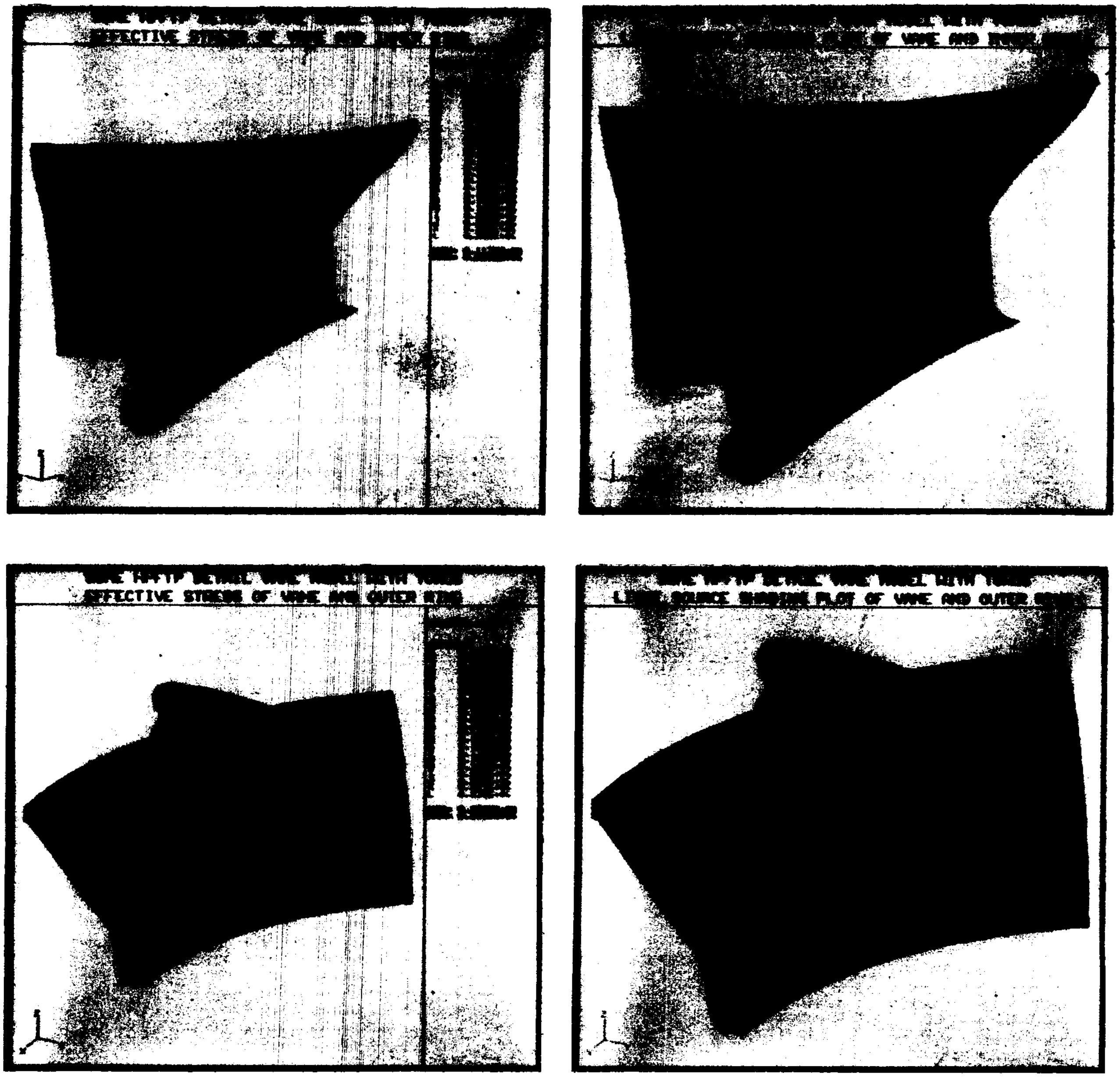


Figure 21 HPFTP Inlet Housing - Global Model - Effective Stress Contour Plot of Vane 1 (at Max Torus Radius) at FPL



ORIGINAL PAGE
COLOR PHOTOGRAPH

Figure 22 HPFTP Inlet Housing - Detailed Vane Submodel - Effective Stress Color Contour Plot of Vane and Ring Intersections

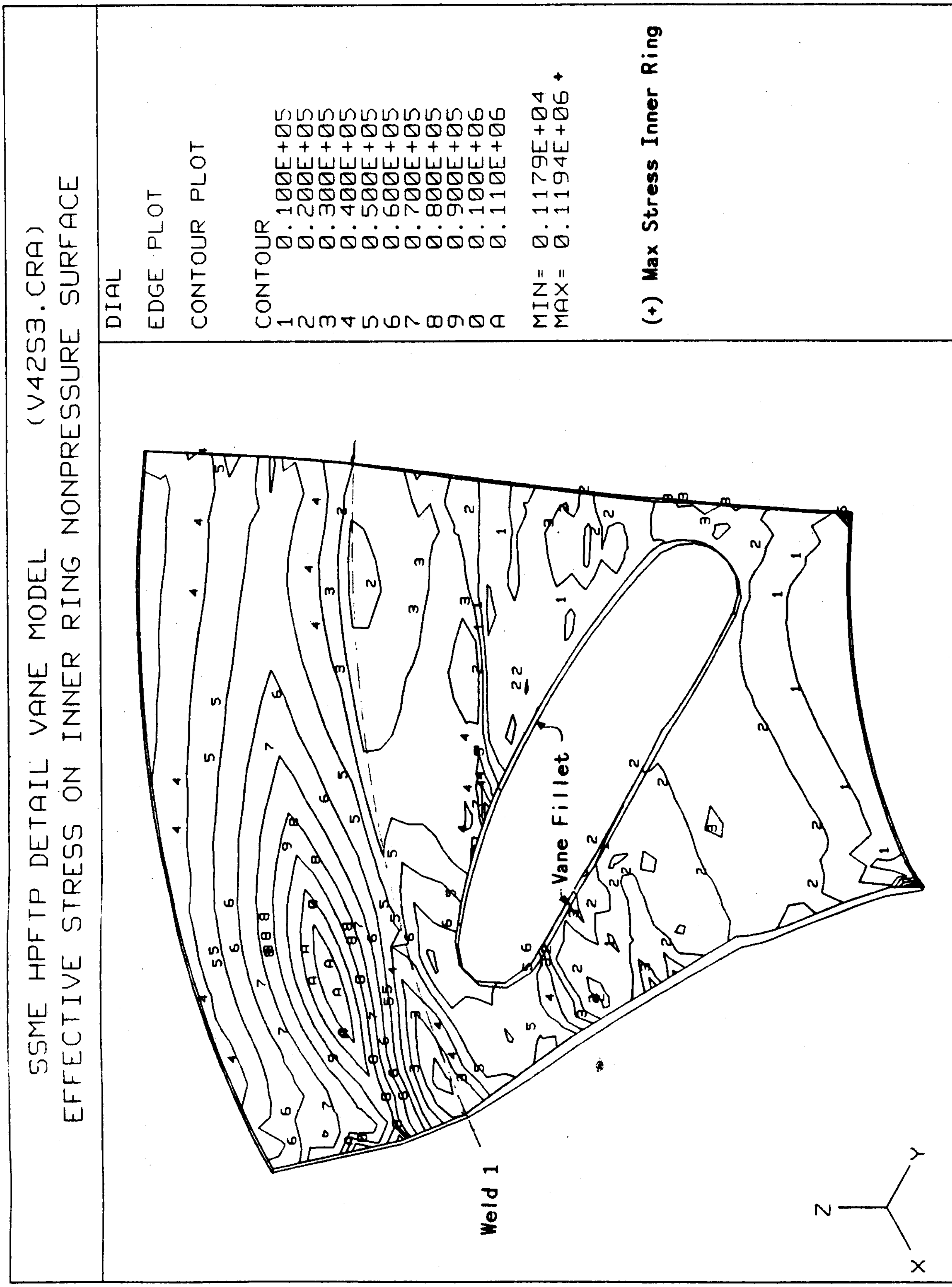


Figure 23 HPFTP Inlet Housing - Detailed Vane Submodel - Effective Stress Contour Plot of Inner Ring Non-Pressure Surface

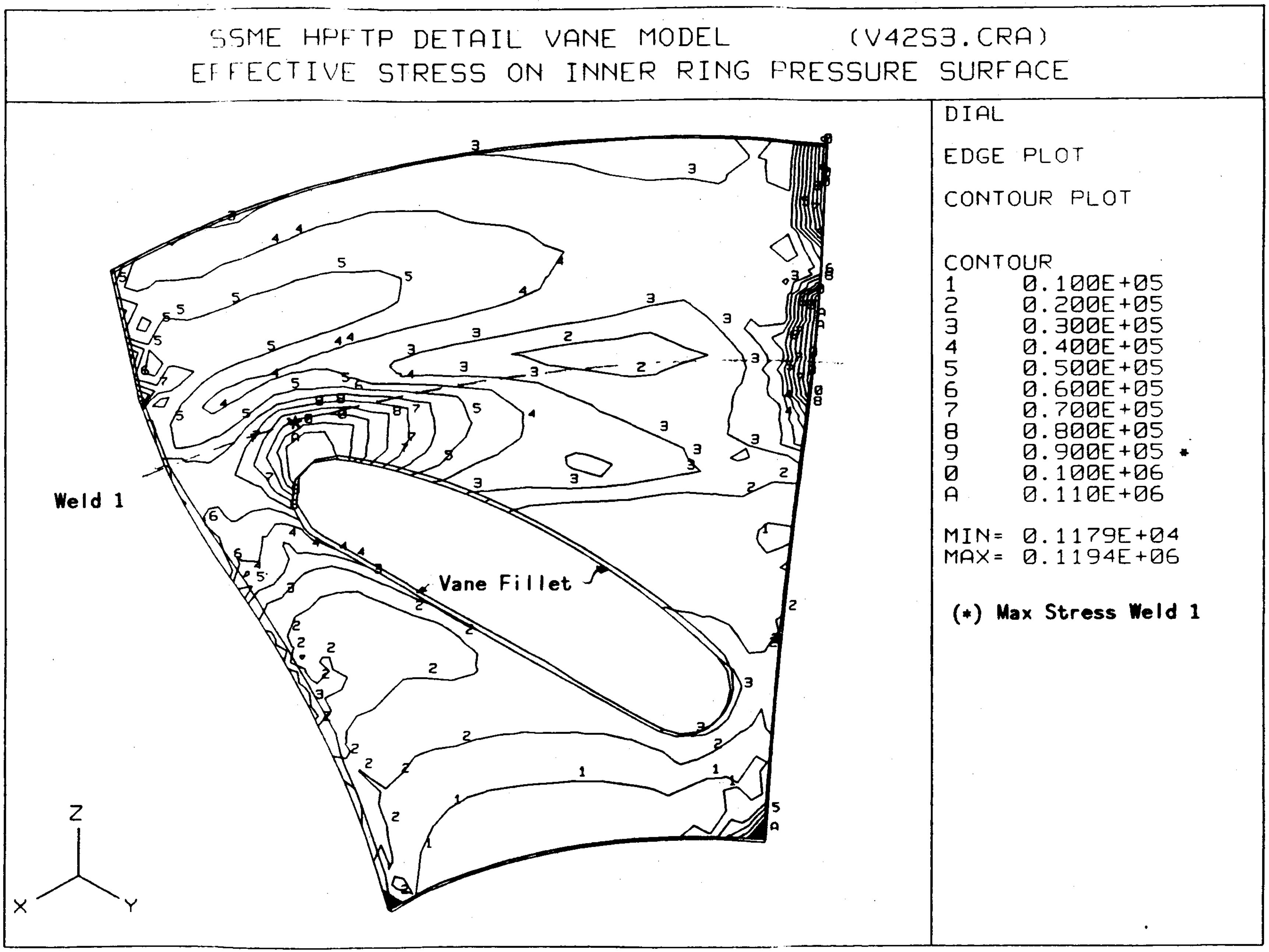


Figure 24 HPFTP Inlet Housing - Detailed Vane Submodel - Effective Stress Contour Plot of Inner Ring Pressure Surface

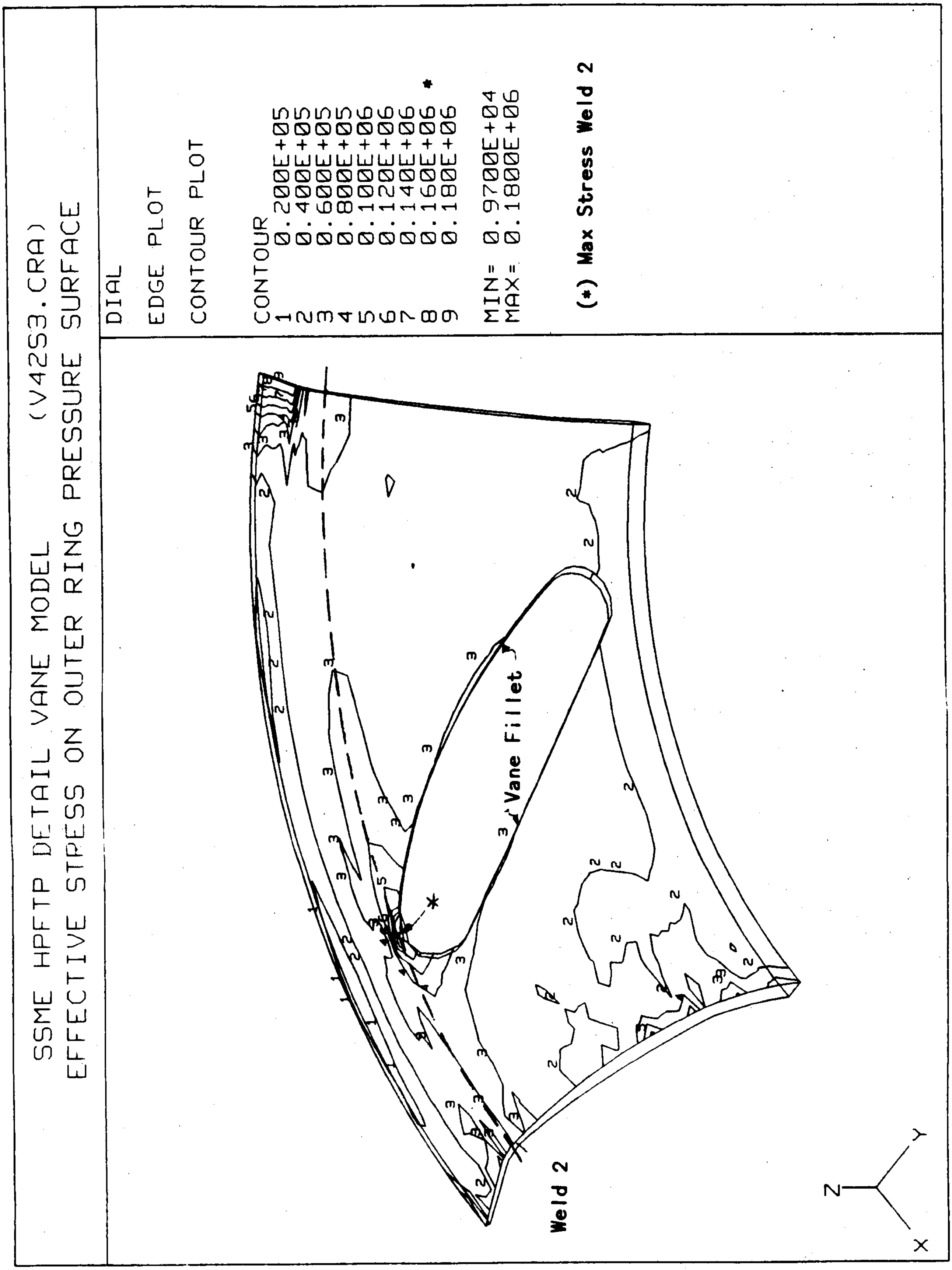


Figure 25 HPFTP Inlet Housing - Detailed Vane Submodel - Effective Stress Contour Plot of Outer Ring Pressure Surface

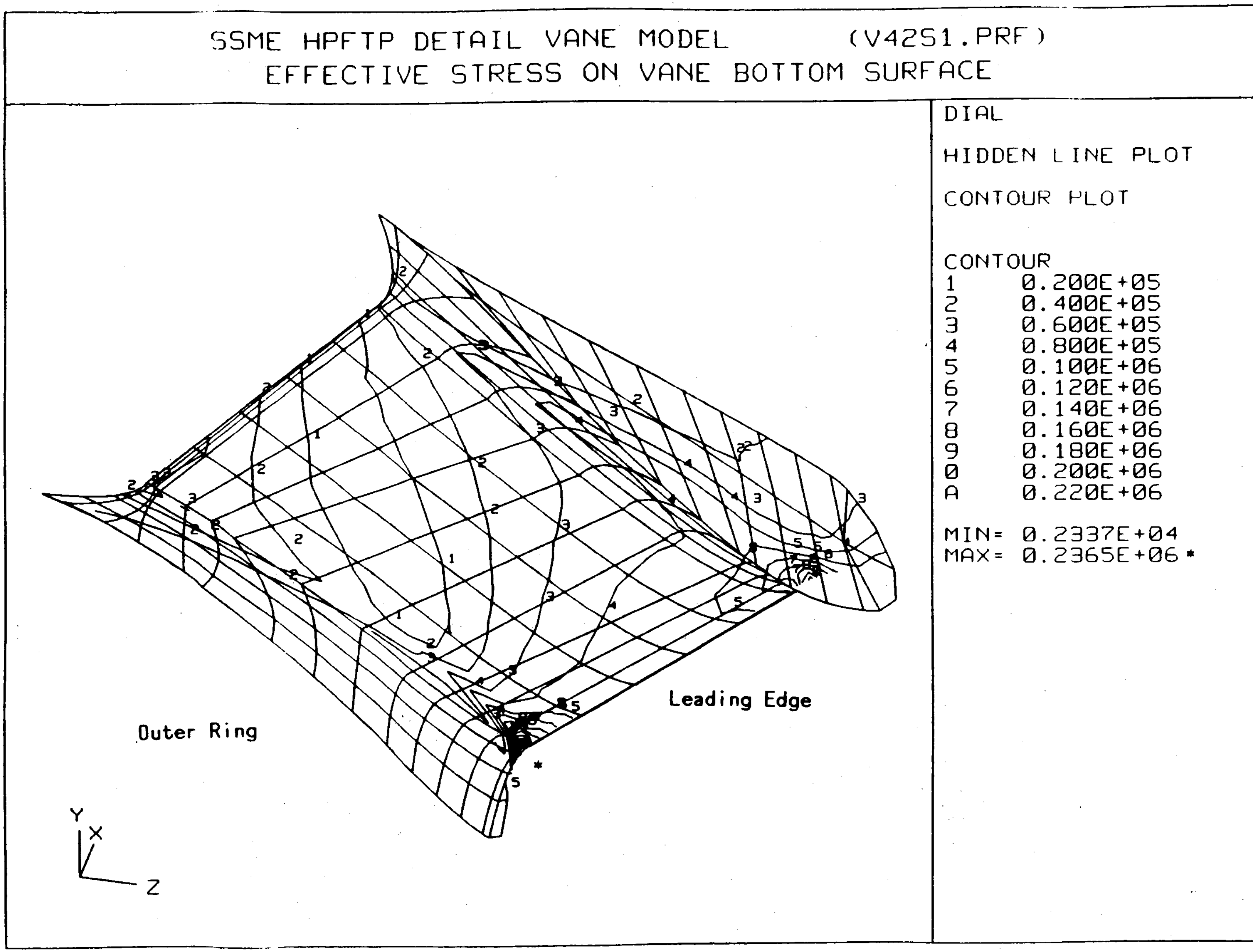


Figure 26 HPFTP Inlet Housing - Detailed Vane Submodel - Effective Stress Contour Plot of Vane and Fillet

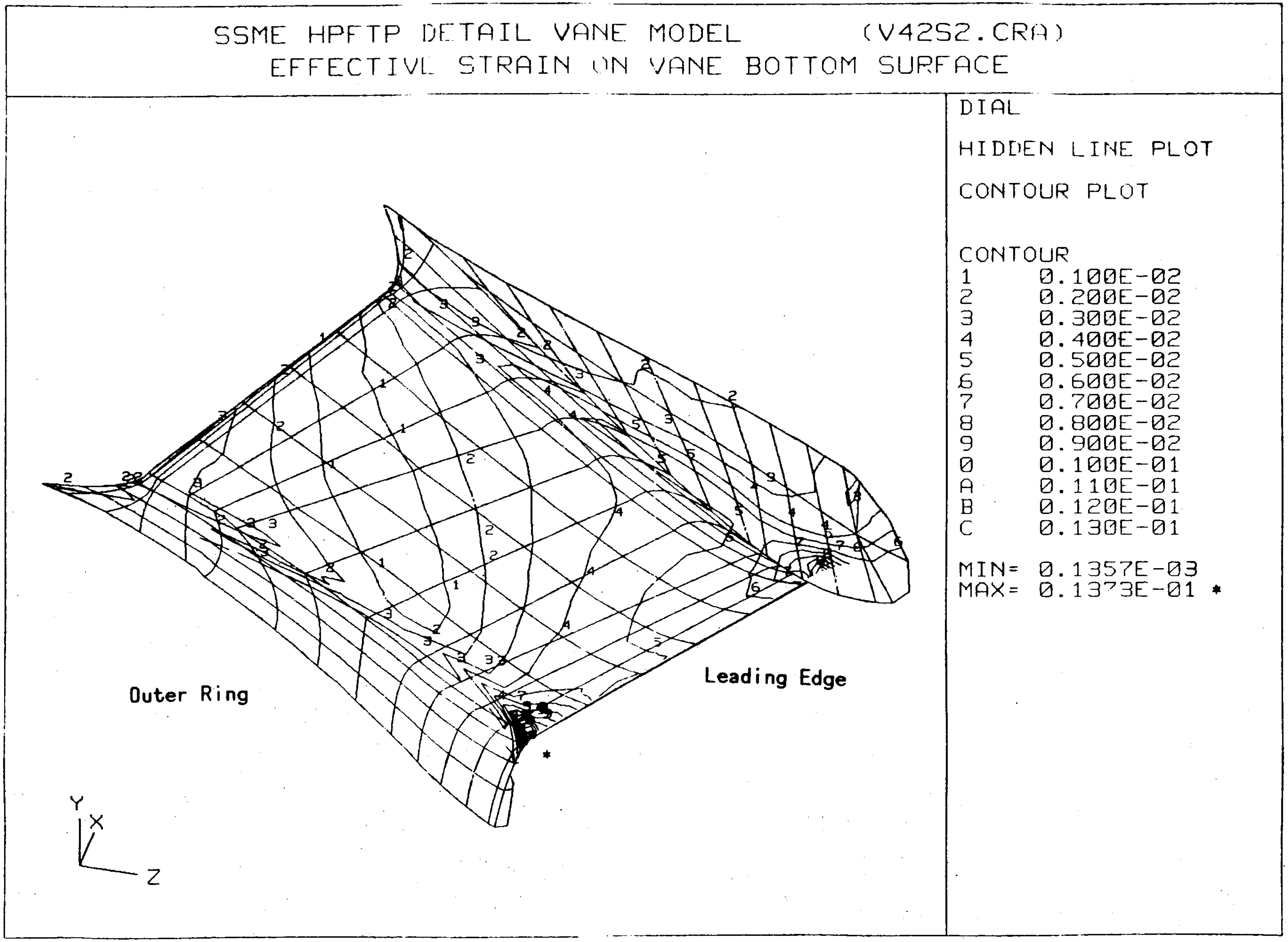


Figure 27 HPFTP Inlet Housing - Detailed Vane Submodel - Effective Strain Contour Plot of Vane and Fillet

Appendix A

FINAL GLOBAL HPFTP INLET HOUSING DIAL FINITE ELEMENT MODEL RUNSTREAM

```
FETCH,DN=MESH,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]MESH.CEX'.
MESH.
FETCH,DN=BAND,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]BAND.CEX'.
BAND.
FETCH,DN=SETUP,DF=TR,TEXT='DIAL$CRAY:SETUP.CEX'.
SETUP.
FETCH,DN=MATL,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]MATL.CEX'.
MATL.
FETCH,DN=LOAD,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]LOAD.CEX'.
LOAD.
FETCH,DN=SOLVE,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]SOLVE.CEX'.
SOLVE.
FETCH,DN=SCOPE,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]SCOPE.CEX'.
SCOPE.
DISPOSE,DN=FT10,TEXT='DISK6:[KPOOL]FOR010.DAT'.
FETCH,DN=UTILITY,DF=TR,TEXT='DISKB:[FERGUSON.CEXL3D2]UTILITY.CEX'.
UTILITY.
DISPOSE,DN=BCD1,DF=BB,TEXT='DISK6:[KPOOL]HYBRID5.PUN'.
BAD.
EXIT.
SAVE,DN=FIL002,PDN=HPFTP,ID=KPOOL,NA.
DISPOSE,DN=FIL002,DF=TR,TEXT='HPFTP-INLET.DB'.
EXIT.
EXIT.
FETCH,DN=FIL002,DF=TR,TEXT='HPFTP-INLET.DB'.
ACCESS,DN=FIL002,PDN=HPFTP,ID=KPOOL,UQ.
ASSIGN,DN=FIL002,LM=300000,U.
/EOF
$ MESH
  CLEAR -1
  MAX/MXPOINT=8725 15000 15000
  ELTYPE 4,1,6
  ASSIGN IPAL=0
REMARK '
REMARK ' ***************************************************************
REMARK ' SPACE SHUTTLE MAIN ENGINE HIGH PRESSURE FUEL TURBO PUMP (HPFTP)
REMARK ' Vanes are modified to extend into inner and  outer rings
REMARK ' (1 layer of elements ) so that there is moment transfered.
REMARK ' ALL NEW LOADS ARE APPLIED - FPL
REMARK ' ***************************************************************
REMARK '
  SET SYNTAX ON
DEFSYS 1 1 3M0.0, 1.0,0.0,0.0 0.0,1.0,0.0    #CYLINDRICAL COORD SYSTEM
DEFSYS 11 1 0.0,-0.000001,0. -1.0,-0.000001,0.0 0.0,-1.0,0.0
REMARK '
REMARK ' *************************************
REMARK ' * AXISYMMETRIC SOLID ELEMENT MESHES *
REMARK ' * IN MAIN BODY OF PUMP BELOW TOROID *   HYBRID SOLID ELEMS
REMARK ' *          THREE MESHES             *
REMARK ' *************************************

#MESH POINTS FOR MESH 1 (INNER RING)  THETA=0.0 DEG

#    999981-12C  KVP SSME HPF1 2    1
IJPOINT         1      3      15   2.500000    0.0          4.671000    1
                2      4      15   2.949999    0.0          4.790000    1
                3      5      15   3.250000    0.0          4.790000    1
                4      5      13   3.250000    0.0          4.099999    1
                5      4      13   2.865000    0.0          4.099999    1
                6      4      11   2.615000    0.0          3.849999    1
```

7	0	0	2.615000	0.0	3.710355	1
8	4	9	2.749561	0.0	3.488602	1
308	6	9	2.749561	0.0	3.488602	1
9	0	0	2.931933	0.0	3.469481	1
10	6	11	3.136975	0.0	3.595601	1
11	6	13	3.331487	0.0	3.731799	1
12	6	15	3.525998	0.0	3.867997	1
315	7	15	0.0	0.0		
17	8	15	3.563346	0.0	3.814658	1
18	8	13	3.406328	0.0	3.624912	1
19	8	11	3.230719	0.0	3.461722	1
20	8	9	2.968478	0.0	3.257798	1
21	8	7	2.726711	0.0	3.030447	1
22	8	5	2.511195	0.0	2.778073	1
23	8	3	2.324505	0.0	2.503693	1
24	8	1	2.069802	0.0	1.969996	1
25	6	1	2.030000	0.0	2.168929	1
26	6	3	2.230315	0.0	2.560510	1
27	0	0	2.333184	0.0	2.781142	1
28	4	5	2.349998	0.0	3.023998	1
328	6	5	2.349998	0.0	3.023998	1
29	3	5	2.193999	0.0	3.179998	1
30	1	5	1.849999	0.0	3.179999	1
31	1	9	1.849999	0.0	3.570000	1
32	2	9	2.139997	0.0	3.570000	1
33	3	9	2.500000	0.0	3.569999	1
133	3	10				

#MESH 2 POINTS

IJPOINT	40	15	1	3.116799	0.0	1.339998	1
	41	15	3	3.274999	0.0	1.339998	1
	42	13	3	3.362834	0.0	1.667802	1
	43	11	3	3.573189	0.0	1.808357	1
	143	12	3				
	44	11	4	3.740000	0.0	1.618148	1
	45	12	4	3.740000	0.0	1.209999	1
	46	13	4	3.987499	0.0	1.209999	1
	47	15	4	3.987499	0.0	1.089999	1
	48	15	6	4.325000	0.0	1.089999	1
	49	19	6	4.325000	0.0	0.550000	1
	50	19	8	4.485000	0.0	0.550000	1
	51	21	8	4.484999	0.0	-0.111607	1
	52	25	8	5.439998	0.0	-0.280000	1
	53	25	6	6.067499	0.0	-0.280000	1
	54	26	6	6.067499	0.0	-0.176000	1
	55	26	8	5.637500	0.0	-0.176000	1
	56	26	10	5.637500	0.0	0.200000	1
	72	7	6	4.075229	0.0	2.158201	1
	73	0	0	4.008238	0.0	2.158201	1
	74	7	3	3.912857	0.0	2.221931	1
	75	0	0	3.969543	0.0	2.368747	1
	76	5	3	4.045116	0.0	2.444320	1
	77	3	3	4.154998	0.0	2.554201	1
	78	1	3	4.195000	0.0	2.554202	1
	84	1	2				
	85	1	1	4.195000	0.0	2.662999	1
	86	3	1	4.138799	0.0	2.662999	1
	87	5	1	3.888425	0.0	2.579901	1
	88	7	1	3.642982	0.0	2.411384	1

	89	9	1	3.438335	0.0	2.194444	1
	90	11	1	3.279151	0.0	1.942248	1
	91	13	1	3.171350	0.0	1.664181	1
	93	9	6	4.120360	0.0	1.759949	1
	94	11	6	4.010991	0.0	1.632932	1
	95	12	6	4.023471	0.0	1.465781	1
	96	13	6	4.150488	0.0	1.356413	1
	97	13	8	4.417089	0.0	1.268602	1
	98	15	8	4.499999	0.0	1.124999	1
	99	17	8	4.500000	0.0	0.875000	1
	100	17	10	4.650000	0.0	0.875000	1
	101	21	10	4.649999	0.0	0.216948	1
	102	22	10	4.782215	0.0	0.059379	1
	103	24	10	5.252214	0.0	-0.023495	1
	104	25	10	5.440000	0.0	0.134075	1

#MESH 3 POINTS

IJPOINT	57	12	6	6.247499	0.0	0.200000	1
	157	11	6				
	58	10	6	6.247499	0.0	0.660000	1
	59	9	6	6.457225	0.0	0.849284	1
	159	9	7				
	60	9	8	7.199999	0.0	-0.000001	1
	61	9	9	7.975501	0.0	-0.000001	1
	62	9	12	8.524999	0.0	-1.322000	1
	63	9	14	8.525000	0.0	-3.160000	1
	64	8	14	9.349999	0.0	-2.810999	1
	65	7	14	9.825000	0.0	-2.810999	1
	66	7	12	9.825000	0.0	-1.580000	1
	67	8	12	9.334236	0.0	-1.448501	1
	68	8	9	8.485347	0.0	0.504793	1
	69	8	8	7.914613	0.0	0.893628	1
	70	8	6	6.683242	0.0	1.299203	1
	71	7	6	5.960766	0.0	1.537164	1
	92	2	4	4.287511	0.0	1.772429	1
	105	11	1	5.440000	0.0	0.390000	1
	106	11	2	5.549999	0.0	0.390000	1
	107	10	2	5.549999	0.0	0.590000	1
	108	10	4	5.852603	0.0	0.676646	1
	109	9	4	5.975420	0.0	0.895178	1
	110	8	4	5.927133	0.0	1.141163	1
	111	7	4	5.730817	0.0	1.297049	1
	201	0	0	2.865000	0.0	3.849999	1
	204	0	0	4.924999	0.0	0.935000	1
	202	0	0	2.193999	0.0	3.023999	1
	203	0	0	2.06033	0.0	4.929980	1
	205	0	0	6.240000	0.0	4.188000	1
	206	0	0	2.055000	0.0	4.903000	1
	207	0	0	4.219000	0.0	1.564420	1
	208	0	0	5.617370	0.0	0.952625	1
	209	0	0	4.810000	0.0	0.216948	1
	210	0	0	5.280000	0.0	0.134075	1
	211	0	0	3.548150	0.0	1.618150	1
	212	0	0	7.523570	0.0	-0.293631	1
	213	0	0	6.660000	0.0	-1.322000	1
	214	0	0	5.550000	0.0	-1.932000	1
	215	0	0	6.450240	0.0	0.646194	1
	216	0	0	5.930320	0.0	-0.360994	1

```
REMARK '*********************************************************************
REMARK ' MESH 1 - INNER RING
REMARK '*********************************************************************


SLINES 30,29
CIRCLE 29,28,202
SPLINE 28,328,0  28,328,27,26,25
SPLINE 328,26,0  28,328,27,26,25
SPLINE 26,25,0   28,328,27,26,25
SLINES 25,24
SPLINE 24,23,0  24,23,22,21,20,19,18,17
SPLINE 23,22,0  24,23,22,21,20,19,18,17
SPLINE 22,21,0  24,23,22,21,20,19,18,17
SPLINE 21,20,0  24,23,22,21,20,19,18,17
SPLINE 20,19,0  24,23,22,21,20,19,18,17
SPLINE 19,18,0  24,23,22,21,20,19,18,17
SPLINE 18,17,0  24,23,22,21,20,19,18,17
SLINES 17,12,11,10
SPLINE 10,308,0  10,9,308,7,6
SLINE 308,8
SPLINE 8,6,0  10,9,8,7,6
CIRCLE 6,5,201
SLINES 5,4,3,2,1,33,32,31,30

SLINES 10,19:33,8:8,28:308,328:33,29

VOID 28 11
VOID 4 12
IJSOLID 0 0 1 HSO 0 _NAME=MSH1
IJSOLID 11 17  1 HSO 0 _NAME=,,,,WLD1
IJSOLID 315 24 1 HSO 0 _NAME=,,INNR,PRES
KNAME 2 2 1 31 INNR,BOLT
IJNAME 21 8 INSD,VANE
IJNAME 19 10 INSD,VANE
IJNAME 23 26 INSD,VANE

IJNAME 1 133 P208,FAC2
IJNAME 31 30 P208,FAC2
IJNAME 31 32 P208,FAC4
IJNAME 30 28 P208,FAC1
IJNAME 328 25 P208,FAC2

PRISM 31 0. 0. 0. 3 360. 1. 0. 0. 0. 0. 0. 0.

MESH 1
 MERGE

REMARK '*********************************************************************
REMARK ' MESH 2 - OUTER RING
REMARK '*********************************************************************

SLINE 85,86
SPLINE 86,87,0 85,86,87,88,89,90,91,40
SPLINE 87,88,0 85,86,87,88,89,90,91,40
SPLINE 88,89,0 85,86,87,88,89,90,91,40
SPLINE 89,90,0 85,86,87,88,89,90,91,40
SPLINE 90,91,0 85,86,87,88,89,90,91,40
```

```
SPLINE 91,40,0 85,86,87,88,89,90,91,40
SLINES 40 41 42
CIRCLE 42,43,211:43,44,211
SLINES 44T56,104
CIRCLE 104,103,210
SLINE 103,102
CIRCLE 102,101,209
SLINES 101,100,99,98,97,96
CIRCLE 96,95,207:95,94,207:94,93,207
SLINES 93,72
SPLINE 72,74,0 72,73,74,75,76
SPLINE 74,76,0 72,73,74,75,76
SLINE 76,77,78,85

SLINES 86,77:88,74:44,94:52,55:87,76:42,91:74,43
SLINES 96,46:96,48:98,48:99,50:93,89
SLINES 51,101
IJSOLID 0 0 1 HSO 0 _NAME=MSH2
IJSOLID 78 86 1 HSO 0 _NAME=,,,,WLD2
IJSOLID 84 40 1 HSO 0 _NAME=,,OUTR,PRES
VOID 43,47
IJNAME 87,76,OUTR,VANE
IJNAME 89,93,OUTR,VANE
IJNAME 91,42,OUTR,VANE

IJNAME 41 143 P208,FAC4
IJNAME 43 44 P208,FAC5
IJNAME 45 47 P208,FAC1
IJNAME 47 48 P438,FAC5
IJNAME 48 49 P438,FAC1
IJNAME 49 50 P438,FAC5
IJNAME 50 51 P438,FAC1
IJNAME 54 56 P777,FAC5

PRISM 31 0. 0. 0. 3 360. 1. 0. 0. 0. 0. 0. 0.

MESH

MERGE
REMARK '********************************************************************
REMARK ' MESH 3 - OUTER RING (PART II)
REMARK '********************************************************************
IJPOINT      56     12      2    5.637500    0.0        0.200000    1
             72      1      6    4.075229    0.0        2.158201    1
             93      1      4    4.120360    0.0        1.759949    1
            104     12      1    5.440000    0.0        0.134075    1

CIRCLE 93,92,207
SLINES 92,111
CIRCLE 111,110,208:110,109,208:109,108,208:108,107,208
SLINES 107,106,105,104,56,57,58
CIRCLE 58,59,215:59,60,216
SLINES 60,61
CIRCLE 61,62,213
SLINES 62T67
CIRCLE 67,68,214:68,69,212
SLINES 69T72,93

SLINES 71,111:70,110:58,108:106,56:69,60:68,61:67,62:64,67
```

```
IJSOLID 0 0 1 HS0 0  NAME=MSH3
KNAME 64 64 1 31 OUTR,BOLT

IJNAME 56 57 P777,FAC5
IJNAME 57 157 P334,FAC4    #51,424 LBS/ 2*PI*R**.46 (SEE IJPOINTS 57,58) + 500 PSI
IJNAME 58 58 P500,FAC4
IJNAME 159 60 P500,FAC5
IJNAME 61 63 P500,FAC5
IJNAME 60 61 P19K,FAC5

PRISM 31 0. 0. 0. 3 360. 1. 0. 0. 0. 0. 0. 0.

MESH
 MERGE
REMARK '
REMARK ' *****************************************
REMARK ' * SHELL ELEMENT MESH MAKING UP TOROID *
REMARK ' * FROM THETA = 0 TO 300 DEGREES       *
REMARK ' *****************************************
#    999981-12C  KVP SSME HPF1 3   1
#########################################################################
#section - 3
#########################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT    1203       1        3        3.525998     0.0      3.867997    1
           1703       1        1        3.563346     0.0      3.814658    1
            303       0        0        2.060328     0.0      4.929984    1
            603       0        0        2.054999     0.0      4.903000    1
           1302       4        3        3.690646     0.0      4.143754    1
           1602       4        1        3.741757     0.0      4.119106    1
           7702       4        2        3.716223     0.0      4.131503    1
           7803      30        3        4.195000     0.0      2.554202    1
           8503      30        1        4.195000     0.0      2.662999    1
           8402      28        1        4.290326     0.0      2.636950    1
           7902      28        3        4.269582     0.0      2.544046    1
           8102      28        2        4.279954     0.0      2.590498    1
           7603       0        0        4.154998     0.0      2.554201    1
           8703       0        0        4.138799     0.0      2.662999    1
#VARYING POINTS
IJPOINT    1303       0        0        3.839394     0.0      4.596750    1
           7703       0        0        3.863730     0.0      4.592191    1
           1603       0        0        3.888068     0.0      4.587631    1
           1503       7        1        3.930226     0.0      4.783211    1
           8603       7        2        3.905653     0.0      4.787814    1
           1403       7        3        3.881081     0.0      4.792418    1
           8403       0        0        4.546110     0.0      2.455962    1
           8103       0        0        4.528584     0.0      2.438040    1
           7903       0        0        4.511099     0.0      2.420265    1
           8303      25        1        4.717591     0.0      2.345176    1
           8003      25        3        4.690458     0.0      2.303178    1
           8203      25        2        4.704024     0.0      2.324177    1
            103      17        2        8.649978     0.0      4.182926    1
            503       0        0        6.240000     0.0      4.182997    1

#########################################################################
#Section - 5
#########################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT    1205       1        3        3.525998     30.0      3.867997    1
           1705       1        1        3.563346     30.0      3.814658    1
```

```
                305       0       0      2.060328     30.0       4.929984     1
                605       0       0      2.054999     30.0       4.903000     1
               1304       4       3      3.690646     30.0       4.143754     1
               1604       4       1      3.741757     30.0       4.119106     1
               7704       4       2      3.716223     30.0       4.131503     1
               7805      30       3      4.195000     30.0       2.554202     1
               8505      30       1      4.195000     30.0       2.662999     1
               8404      28       1      4.290326     30.0       2.636950     1
               7904      28       3      4.269582     30.0       2.544046     1
               8104      28       2      4.279954     30.0       2.590498     1
               7605       0       0      4.154998     30.0       2.554201     1
               8705       0       0      4.138799     30.0       2.662999     1
#VARYING POINTS
IJPOINT        1305       0       0      3.834550   30.0     4.571858     1
               1605       0       0      3.883470   30.0     4.561982     1
               1505       7       1      3.928404   30.0     4.756945     1
               1405       7       3      3.879393   30.0     4.766839     1
               8405       0       0      4.539644   30.0     2.462191     1
               7905       0       0      4.505280   30.0     2.425872     1
               8305      25       1      4.710428   30.0     2.351691     1
               8005      25       3      4.683267   30.0     2.309711     1
               8105       0       0      4.522462   30.0     2.444031     1
               8205      25       2      4.696847   30.0     2.330701     1
               7705       0       0      3.859010   30.0     4.566920     1
               8605       7       2      3.903898   30.0     4.761891     1
                105      17       2      8.440594   30.0     4.142996     1
                505       0       0      6.129998   30.0     4.142996     1
############################################################################
#Section - 7
############################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT        1207       1       3      3.525998     60.0       3.867997     1
               1707       1       1      3.563346     60.0       3.814658     1
                307       0       0      2.060328     60.0       4.929984     1
                607       0       0      2.054999     60.0       4.903000     1
               1306       4       3      3.690646     60.0       4.143754     1
               1606       4       1      3.741757     60.0       4.119106     1
               7706       4       2      3.716223     60.0       4.131503     1
               7807      30       3      4.195000     60.0       2.554202     1
               8507      30       1      4.195000     60.0       2.662999     1
               8406      28       1      4.290326     60.0       2.636950     1
               7906      28       3      4.269582     60.0       2.544046     1
               8106      28       2      4.279954     60.0       2.590498     1
               7607       0       0      4.154998     60.0       2.554201     1
               8707       0       0      4.138799     60.0       2.662999     1
#VARYING POINTS
IJPOINT        1307       0       0      3.827292   60.0     4.537622     1
               1607       0       0      3.876534   60.0     4.526687     1
               1507       7       1      3.926016   60.0     4.720570     1
               1407       7       3      3.877205   60.0     4.731409     1
               8407       0       0      4.531909   60.0     2.469357     1
               7907       0       0      4.498318   60.0     2.432321     1
               8307      25       1      4.697639   60.0     2.354384     1
               8007      25       3      4.669139   60.0     2.313302     1
               8107       0       0      4.515113   60.0     2.450838     1
               8207      25       2      4.683389   60.0     2.333843     1
               7707       0       0      3.851912   60.0     4.532154     1
               8607       7       2      3.901610   60.0     4.725989     1
                107      17       2      8.193307   60.0     4.087998     1
                507       0       0      6.000000   60.0     4.087998     1
```

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######################################################################
#Section - 9
######################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1209     1      3      3.525998    90.0     3.867997   1
          1709     1      1      3.563346    90.0     3.814658   1
           309     0      0      2.060328    90.0     4.929984   1
           609     0      0      2.054999    90.0     4.903000   1
          1308     4      3      3.690646    90.0     4.143754   1
          1608     4      1      3.741757    90.0     4.119106   1
          7708     4      2      3.716223    90.0     4.131503   1
          7809    30      3      4.195000    90.0     2.554202   1
          8509    30      1      4.195000    90.0     2.662999   1
          8408    28      1      4.290326    90.0     2.636950   1
          7908    28      3      4.269582    90.0     2.544046   1
          8108    28      2      4.279954    90.0     2.590498   1
          7609     0      0      4.154998    90.0     2.554201   1
          8709     0      0      4.138799    90.0     2.662999   1
#VARYING POINTS
IJPOINT   1309     0      0      3.819539   90.0   4.504210   1
          1609     0      0      3.869071   90.0   4.492221   1
          1509     7      1      3.922709   90.0   4.685012   1
          1409     7      3      3.874111   90.0   4.696774   1
          8409     0      0      4.523301   90.0   2.476985   1
          7909     0      0      4.490571   90.0   2.439186   1
          8309    25      1      4.686240   90.0   2.359630   1
          8009    25      3      4.657018   90.0   2.319057   1
          8109     0      0      4.506936   90.0   2.458085   1
          8209    25      2      4.671629   90.0   2.339343   1
          7709     0      0      3.844304   90.0   4.498215   1
          8609     7      2      3.898410   90.0   4.690893   1
           109    17      2      7.956713   90.0   4.037998   1
           509     0      0      5.875000   90.0   4.037998   1
######################################################################
#Section 11
######################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1211     1      3      3.525998   120.0     3.867997   1
          1711     1      1      3.563346   120.0     3.814658   1
           311     0      0      2.060328   120.0     4.929984   1
           611     0      0      2.054999   120.0     4.903000   1
          1310     4      3      3.690646   120.0     4.143754   1
          1610     4      1      3.741757   120.0     4.119106   1
          7710     4      2      3.716223   120.0     4.131503   1
          7811    30      3      4.195000   120.0     2.554202   1
          8511    30      1      4.195000   120.0     2.662999   1
          8410    28      1      4.290326   120.0     2.636950   1
          7910    28      3      4.269582   120.0     2.544046   1
          8110    28      2      4.279954   120.0     2.590498   1
          7611     0      0      4.154998   120.0     2.554201   1
          8711     0      0      4.138799   120.0     2.662999   1
#VARYING POINTS
IJPOINT   1311     0      0      3.810061  120.0   4.466805   1
          1611     0      0      3.859895  120.0   4.453612   1
          1511     7      1      3.918268  120.0   4.645047   1
          1411     7      3      3.869933  120.0   4.657844   1
          8411     0      0      4.511195  120.0   2.487138   1
          7911     0      0      4.479675  120.0   2.448324   1
          8311    25      1      4.676920  120.0   2.373953   1
          8011    25      3      4.648720  120.0   2.332664   1
```

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          8111      0      0       4.495435   120.0   2.467731     1
          8211     25      2       4.662820   120.0   2.353308     1
          7711      0      0       3.834978   120.0   4.460209     1
          8611      7      2       3.894100   120.0   4.651445     1
           111     17      2       7.682194   120.0   3.987990     1
           511      0      0       5.729998   120.0   3.987990     1
######################################################################
#Section 13
######################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1213      1      3       3.525998    150.0      3.867997     1
          1713      1      1       3.563346    150.0      3.814658     1
           313      0      0       2.060328    150.0      4.929984     1
           613      0      0       2.054999    150.0      4.903000     1
          1312      4      3       3.690646    150.0      4.143754     1
          1612      4      1       3.741757    150.0      4.119106     1
          7712      4      2       3.716223    150.0      4.131503     1
          7813     30      3       4.195000    150.0      2.554202     1
          8513     30      1       4.195000    150.0      2.662999     1
          8412     28      1       4.290326    150.0      2.636950     1
          7912     28      3       4.269582    150.0      2.544046     1
          8112     28      2       4.279954    150.0      2.590498     1
          7613      0      0       4.154998    150.0      2.554201     1
          8713      0      0       4.138799    150.0      2.662999     1
#VARYING POINTS
IJPOINT   1313      0      0       3.796484   150.0   4.418265     1
          1613      0      0       3.846666   150.0   4.403473     1
          1513      7      1       3.915975   150.0   4.591550     1
          1413      7      3       3.868014   150.0   4.605687     1
          8413      0      0       4.496839   150.0   2.498368     1
          7913      0      0       4.466755   150.0   2.458431     1
          8313     25      1       4.663096   150.0   2.386676     1
          8013     25      3       4.635214   150.0   2.345172     1
          8113      0      0       4.481796   150.0   2.478399     1
          8213     25      2       4.649155   150.0   2.365924     1
          7713      0      0       3.821575   150.0   4.410869     1
          8613      7      2       3.891994   150.0   4.598619     1
           113     17      2       7.365129   150.0   3.922998     1
           513      0      0       5.570000   150.0   3.922998     1
######################################################################
#Section 15
######################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1215      1      3       3.525998    180.0      3.867997     1
          1715      1      1       3.563346    180.0      3.814658     1
           315      0      0       2.060328    180.0      4.929984     1
           615      0      0       2.054999    180.0      4.903000     1
          1314      4      3       3.690646    180.0      4.143754     1
          1614      4      1       3.741757    180.0      4.119106     1
          7714      4      2       3.716223    180.0      4.131503     1
          7815     30      3       4.195000    180.0      2.554202     1
          8515     30      1       4.195000    180.0      2.662999     1
          8414     28      1       4.290326    180.0      2.636950     1
          7914     28      3       4.269582    180.0      2.544046     1
          8114     28      2       4.279954    180.0      2.590498     1
          7615      0      0       4.154998    180.0      2.554201     1
          8715      0      0       4.138799    180.0      2.662999     1
#VARYING POINTS
IJPOINT   1315      0      0       3.782863   180.   4.374143     1
          1615      0      0       3.833319   180.   4.357860     1
```

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          1515      7       1       3.907163   180.    4.544185    1
          1415      7       3       3.859579   180.    4.559540    1
          8415      0       0       4.424942   180.    2.552450    1
          7915      0       0       4.398211   180.    2.497786    1
          8315     25       1       4.593356   180.    2.441578    1
          8015     25       3       4.565862   180.    2.3998    1
          8115      0       0       4.411576   180.    2.525118    1
          8215     25       2       4.579609   180.    2.420696    1
          7715      0       0       3.808090   180.    4.366001    1
          8615      7       2       3.883370   180.    4.551862    1
           115     17       2       7.090474   180.    3.872999    1
           515      0       0       5.415000   180.    3.872999    1
#################################################################
#Section 17
#################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1217      1       3       3.525998    210.0     3.867997    1
          1717      1       1       3.563346    210.0     3.814658    1
           317      0       0       2.060328    210.0     4.929984    1
           617      0       0       2.054999    210.0     4.903000    1
          1316      4       3       3.690646    210.0     4.143754    1
          1616      4       1       3.741757    210.0     4.119106    1
          7716      4       2       3.716223    210.0     4.131503    1
          7817     30       3       4.195000    210.0     2.554202    1
          8517     30       1       4.195000    210.0     2.662999    1
          8416     28       1       4.290326    210.0     2.636950    1
          7916     28       3       4.269582    210.0     2.544046    1
          8116     28       2       4.279954    210.0     2.590498    1
          7617      0       0       4.154998    210.0     2.554201    1
          8717      0       0       4.138799    210.0     2.662999    1
#VARYING POINTS
IJPOINT   1317      0       0       3.763176   210.    4.316481    1
          1617      0       0       3.813922   210.    4.298196    1
          1517      7       1       3.894891   210.    4.485970    1
          1417      7       3       3.846293   210.    4.497732    1
          8417      0       0       4.379584   210.    2.585257    1
          7917      0       0       4.352711   210.    2.518019    1
          8317     25       1       4.553713   210.    2.482040    1
          8017     25       3       4.528217   210.    2.439029    1
          8117      0       0       4.366147   210.    2.551638    1
          8217     25       2       4.540965   210.    2.460534    1
          7717      0       0       3.788548   210.    4.307338    1
          8617      7       2       3.870592   210.    4.491851    1
           117     17       2       6.740663   210.    3.813000    1
           517      0       0       5.224999   210.    3.813000    1
#################################################################
#Section 19
#################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1219      1       3       3.525998    240.0     3.867997    1
          1719      1       1       3.563346    240.0     3.814658    1
           319      0       0       2.060328    240.0     4.929984    1
           619      0       0       2.054999    240.0     4.903000    1
          1318      4       3       3.690646    240.0     4.143754    1
          1618      4       1       3.741757    240.0     4.119106    1
          7718      4       2       3.716223    240.0     4.131503    1
          7819     30       3       4.195000    240.0     2.554202    1
          8519     30       1       4.195000    240.0     2.662999    1
          8418     28       1       4.290326    240.0     2.636950    1
          7918     28       3       4.269582    240.0     2.544046    1
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          8118      28       2        4.279954    240.0       2.590498    1
          7619       0       0        4.154998    240.0       2.554201    1
          8719       0       0        4.138799    240.0       2.662999    1
#VARYING POINTS
IJPOINT   1319       0       0        3.735987    240.    4.245709    1
          1619       0       0        3.786980    240.    4.224884    1
          1519       7       1        3.874114    240.    4.405333    1
          1419       7       3        3.827825    240.    4.424236    1
          8419       0       0        4.336511    240.    2.612899    1
          7919       0       0        4.311336    240.    2.532804    1
          8319      25       1        4.520979    240.    2.532796    1
          8019      25       3        4.501063    240.    2.486933    1
          8119       0       0        4.323923    240.    2.572851    1
          8219      25       2        4.511021    240.    2.509864    1
          7719       0       0        3.761483    240.    4.235296    1
          8619       7       2        3.850969    240.    4.414784    1
           119      17       2        6.338047    240.    3.747998    1
           519       0       0        5.004999    240.    3.747998    1
##########################################################################
#Section 21
##########################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1221       1       3        3.525998    270.0       3.867997    1
          1721       1       1        3.563346    270.0       3.814658    1
           321       0       0        2.060328    270.0       4.929984    1
           621       0       0        2.054999    270.0       4.903000    1
          1320       4       3        3.690646    270.0       4.143754    1
          1620       4       1        3.741757    270.0       4.119106    1
          7720       4       2        3.716223    270.0       4.131503    1
          7821      30       3        4.195000    270.0       2.554202    1
          8521      30       1        4.195000    270.0       2.662999    1
          8420      28       1        4.290326    270.0       2.636950    1
          7920      28       3        4.269582    270.0       2.544046    1
          8120      28       2        4.279954    270.0       2.590498    1
          7621       0       0        4.154998    270.0       2.554201    1
          8721       0       0        4.138799    270.0       2.662999    1
#VARYING POINTS
IJPOINT   1321       0       0        3.690667    270.    4.143827    1
          1621       0       0        3.741778    270.    4.119180    1
          1521       7       1        3.842451    270.    4.292672    1
          1421       7       3        3.797414    270.    4.314390    1
          8421       0       0        4.290326    270.    2.636950    1
          7921       0       0        4.269582    270.    2.544046    1
          8321      25       1        4.482183    270.    2.578427    1
          8021      25       3        4.467595    270.    2.530602    1
          8121       0       0        4.279954    270.    2.590498    1
          8221      25       2        4.474889    270.    2.554515    1
          7721       0       0        3.716223    270.    4.131503    1
          8621       7       2        3.819932    270.    4.303531    1
           121      17       2        5.876244    270.    3.652999    1
           521       0       0        4.745000    270.    3.652999    1
##########################################################################
#Section 23
##########################################################################
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   1223       1       3        3.525998    300.0       3.867997    1
          1723       1       1        3.563346    300.0       3.814658    1
           323       0       0        2.060328    300.0       4.929984    1
           623       0       0        2.054999    300.0       4.903000    1
          1322       4       3        3.690646    300.0       4.143754    1
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              1622      4       1        3.741757    300.0      4.119106    1
              7722      4       2        3.716223    300.0      4.131503    1
              7823     30       3        4.195000    300.0      2.554202    1
              8523     30       1        4.195000    300.0      2.662999    1
              8422     28       1        4.290326    300.0      2.636950    1
              7922     28       3        4.269582    300.0      2.544046    1
              8122     28       2        4.279954    300.0      2.590498    1
              7623      0       0        4.154998    300.0      2.554201    1
              8723      0       0        4.138799    300.0      2.662999    1
#VARYING POINTS
IJPOINT       1323      0       0        3.690646    300.    4.143754    1
              1623      0       0        3.741757    300.    4.119106    1
              1523      7       1        3.878649    300.    4.243695    1
              1423      7       3        3.848908    300.    4.283832    1
              8423      0       0        4.290326    300.    2.636950    1
              7923      0       0        4.269582    300.    2.544046    1
              8323     25       1        4.491205    300.    2.618833    1
              8023     25       3        4.486713    300.    2.569035    1
              8123      0       0        4.279954    300.    2.590498    1
              8223     25       2        4.488959    300.    2.593933    1
              7723      0       0        3.716223    300.    4.131503    1
              8623      7       2        3.863789    300.    4.263800    1
               123     17       2        5.317389    300.    3.518000    1
               523      0       0        4.415000    300.    3.518000    1
######################################################################
######################################################################
SET SYNTAX ON
DO ;10 &I=0,20,2

IJGRID 3+&I
#CIRCLE 1703+&I,1602+&I,603+&I
SLINES 1703+&I,1602+&I
#SPLINE 1602+&I,1503+&I,0,1703+&I,1602+&I,1603+&I,1503+&I
SLINES 1602+&I,1503+&I

SLINES 1503+&I,8603+&I,1403+&I

#SPLINE 1403+&I,1302+&I,0,1403+&I,1303+&I,1302+&I,1203+&I
SLINES 1403+&I,1302+&I

#CIRCLE 1302+&I,1203+&I,303+&I
SLINES 1302+&I,1203+&I

SLINES 1203+&I,1703+&I:1302+&I,7702+&I,1602+&I

#SPLINE 7702+&I,8603+&I,0,7702+&I,7703+&I,8603+&I
SLINES 7702+&I,8603+&I

IJGRID 103+&I
#SPLINE 8303+&I,8402+&I,0,8303+&I,8403+&I,8402+&I,8503+&I,8703+&I
#SPLINE 8402+&I,8503+&I,0,8303+&I,8403+&I,8402+&I,8503+&I,8703+&I
SLINES 8303+&I,8402+&I,8503+&I

SLINES 8503+&I,7803+&I

#SPLINE 7803+&I,7902+&I,0,7603+&I,7803+&I,7902+&I,7903+&I,8003+&I
#SPLINE 7902+&I,8003+&I,0,7603+&I,7803+&I,7902+&I,7903+&I,8003+&I
SLINES 7803+&I,7902+&I,8003+&I

SLINES 8003+&I,8203+&I,8303+&I:7902+&I,8102+&I,8402+&I
```

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#SPLINE 8102+&I,8203+&I,0,8102+&I,8103+&I,8203+&I
SLINES 8102+&I,8203+&I

IJGRID 203+&I
#SPLINE 7702+&I,8603+&I,0,7702+&I,7703+&I,8603+&I
CIRCLE 8603+&I,103+&I,503+&I:103+&I,8203+&I,503+&I
#SPLINE 8102+&I,8203+&I,0,8102+&I,8103+&I,8203+&I

;10 NOP

#*************************************************************************
MSYS=11
RULE 6 5 7
RULE 11 9 11
RULE 16 13 15
RULE 21 17 19
RULE 26 21 23
IJSOLID 1703 1403 1 HSO 0 _NAME=MSH4
IJSOLID 1703 1302 1 HSO 0 _NAME=MSH4,TORS,WLD1
IJSOLID 1703 8603 1 HSO 0 _NAME=MSH4,,,PRES
KSSHELL 1602 1403  1 4M.025 4MO. 1 FSH 0 0 0 0. EDGE
IJSHELL 1503,8603 .025 .025 0.0 0.0 1 FSH 0 -1 0 0. EDGE
IJSHELL 1403,8603 .025 .025 0.0 0.0 1 FSH 0 -1 0 0. EDGE
MESH/IJGRID=3

 MERGE


MSYS=11
RULE 6 105 107
RULE 11 109 111
RULE 16 113 115
RULE 21 117 119
RULE 26 121 123
IJSOLID 8003 8503 1 HSO 0 _NAME=MSH5
IJSOLID 7902 8503 1 HSO 0 _NAME=MSH5,TORS,WLD2
IJSOLID 8203 8503 1 HSO 0 _NAME=MSH5,,,PRES
IJSHELL 8203,8303 .025 .025 0.0 0.0 1 FSH 0 -1 0 0. EDGE
IJSHELL 8203,8003 .025 .025 0.0 0.0 1 FSH 0 -1 0 0. EDGE
KSSHELL 8303 7902  1 4M.025 4MO. 1 FSH 0 0 0 0. EDGE
MESH/IJGRID=103

 MERGE


MSYS=11
RULE 6 205 207
RULE 11 209 211
RULE 16 213 215
RULE 21 217 219
RULE 26 221 223
IJSHELL 8603,8203 .050 .050 0.0 0.0 1 FSH 0 -1 0 0. _NAME=,,SHLL,PRES
MESH/IJGRID=203

 MERGE
REMARK '
REMARK ' ROTATE AND MIRROR ALL PREVIOUS MESHES
ROTATE -90. 3 1 all
mirror 1 0 0 0 1 all
REMARK '
```

```
REMARK ' ***********************************
REMARK ' * TORUS INTERSECTION MESHES       *
REMARK ' * TOROID FROM 300 TO 360 DEGREES *
REMARK ' ***********************************
REMARK '
  DEFSYS 1 2 -91.08,-6.24,3.1137,-91.06722,-6.24,2.1137 >
             -91.08,-5.24,3.1137 # SYSTEM USED TO DEFINE CONE
  DEFSYS 3 0 -91.08,-6.24,3.1137,-91.09278,-6.24,4.1137 >
             -91.08,-7.24,3.1137 # SYSTEM USED TO DEFINE CONE
  DEFSYS 2 3 0.,0.,3.55,0.,-1.,3.55,1.,0.,3.55,4.38
  DEFSYS 4 1 0.,0.,0.,0.,-1.,0.,1.,0.,0.
  DEFSURFACE 1 1 3 88.5
  DEFSURFACE 2 2 1 .92
REMARK '
REMARK ' MESH A - MESH COMING INTO INTERSECTION - MESH 7
REMARK ' ***************************************
   MSYS 4
  IJPOINT 1 1 1 3.716223   0.   4.131503    4
  IJPOINT 2 1 4 3.716223   0.   4.131503    4
          3 1 5  .92 15. 90. 2 1,2
          4 1 8  .92 35 70. 2 1,2
          5 1 10  .92 53. 60. 2 1
          6 1 14 .92 53. -15. 2 1
          7 1 16 1.4 53. -70. 2 1
          8 1 18 1.2 42. -70. 2 1
          9 1 21 .91 15. -70. 2 1,2
          10 1 22 4.279954   0.   2.590498    4
          11 1 25 4.279954   0.   2.590498    4
  SLINE 2,3
  SINT 3,4,.5
       4,5
  PLINE 5,6,7
  SINT 7,8
       8,9,3.
  SLINE 9 10
  IJGRID 1
  LET &X1 = .5 * 3.716223 + .5 * 3.863789
  LET &Z1 = .5 * 4.131503 + .5 * 4.263800
  LET &X2 = .5 * 4.279954 + .5 * 4.488959
  LET &Z2 = .5 * 2.590498 + .5 * 2.593933
 IJPOINT   29 1 1  3.716223   30.   4.131503    4
           30 1 4  &X1 30. &Z1 4
           31 1 5  .92 31.5 120. 2 2
           32 1 9  .92 47. 60. 2 2
           33 1 14 .92 52. 0. 2 2
           34 1 21 .92 31.5 -80. 2 2
           35 1 22 &X2  30.  &Z2 4
           36 1 25 4.279954 30.   2.590498    4
  SLINE 30,31
  SINT 31,32
       32,33
       33,34
  SLINE 34,35
  IJGRID 2
  IJPOINT 19 1 1   3.716223   60.   4.131503    4
          20 1 4   3.863789 60.   4.263800    4
          21 1 14  5.317389 60.   3.518000    4
          22 1 22  4.488959 60.   2.593933    4
          23 1 25  4.279954 60.   2.590498    4
          24 0       0       4.415000   60.   3.518000    4
```

```
  CIRCLE 20,21,24
  CIRCLE 21,22,24
  KSHELL 20,22,1,6,4M.05,4M.0,1,FSH,0,0,0,0.,SEC1
  RULE 6 1 2
  MESH
  MERGE TYPE=FSH
REMARK '
REMARK ' MESH B - MESH AT SHELL ELEMENT/SOLID ELEMENT INTERFACE - MESH 8
REMARK ' ******************************************************
 MSYS 4
 IJPOINT 9   1  1   4.195000     0.0      2.662999    4
         10  3  1   4.195000     0.0      2.554202    4
 IJPOINT 11  1  3   4.290326   0.   2.636950   4
         12  2  3   4.279954   0.   2.590498   4
         13  3  3   4.269582   0.   2.544046   4
         14  3  6   4.269582   0.   2.544046   4
         15  2  6   4.279954   0.   2.590498   4
         16  1  6   4.290326   0.   2.636950   4
 SLINES 11,9,10,13
 SLINES 11,12,13,14,15,16,11
  LET &X24 = .5 * 4.269582 + .5 * 4.486713
  LET &Z24 = .5 * 2.544046 + .5 * 2.569035
  LET &X25 = .5 * 4.279954 + .5 * 4.488959
  LET &Z25 = .5 * 2.590498 + .5 * 2.593933
  LET &X26 = .5 * 4.290326 + .5 * 4.491205
  LET &Z26 = .5 * 2.636950 + .5 * 2.618833
 IJGRID 1
 IJPOINT 19   1  1   4.195000    30.0     2.662999    4
         20  3  1   4.195000    30.0     2.554202    4
 IJPOINT 21  1  3   4.290326   30.   2.636950   4
         22  2  3   4.279954   30.   2.590498   4
         23  3  3   4.269582   30.   2.544046   4
         24  3  6   &X24       30.   &Z24 4
         25  2  6   &X25       30.   &Z25 4
         26  1  6   &X26       30.   &Z26 4
 SLINES 21,19,20,23
 SLINES 21,22,23,24,25,26,21
 IJGRID 2
 IJPOINT 29   1  1   4.195000    60.0     2.662999    4
         30  3  1   4.195000    60.0     2.554202    4
 IJPOINT 31  1  3   4.290326   60.   2.636950   4
         32  2  3   4.279954   60.   2.590498   4
         33  3  3   4.269582   60.   2.544046   4
         34  3  6   4.486713   60.   2.569035   4
         35  2  6   4.488959   60.   2.593933   4
         36  1  6   4.491205   60.   2.618833   4
 SLINES 31,29,30,33
 SLINES 31,32,33,34,35,36,31
 IJSHELL 34 36 2M.025 2M0. 1 FSH 0 0 0 0. EDGE
 IJSOLID 29,34,1,HS0 0 MSHB
 IJSOLID 29,35,1,HS0 0 MSHB,PRES
 RULE 6 1 2
 MESH
  MERGE
REMARK '
REMARK ' MESH C - MESH AT SHELL ELEMENT/SOLID ELEMENT INTERFACE - MESH 9
REMARK ' ******************************************************
 MSYS 4
 IJPOINT 9   1  1  3.525998     0.0      3.867997    4
         10  3  1  3.563346     0.0      3.814658    4
```

```
IJPOINT 11  1  4  3.690646   0.   4.143754    4
        12  2  4  3.716223   0.   4.131503    4
        13  3  4  3.741757   0.   4.119106    4
        14  3  7  3.741757   0.   4.119106    4
        15  2  7  3.716223   0.   4.131503    4
        16  1  7  3.690646   0.   4.143754    4
SLINES 11,9,10,13
SLINES 11,12,13,14,15,16,11
 LET &X24 = .5 * 3.741757 + .5 * 3.878649
 LET &Z24 = .5 * 4.119106 + .5 * 4.243695
 LET &X25 = .5 * 3.716223 + .5 * 3.863789
 LET &Z25 = .5 * 4.131503 + .5 * 4.263800
 LET &X26 = .5 * 3.690646 + .5 * 3.848908
 LET &Z26 = .5 * 4.143754 + .5 * 4.283832
 IJGRID 1
 IJPOINT 19   1  1  3.525998    30.0     3.867997    4
        20  3  1  3.563346    30.0     3.814658    4
 IJPOINT 21  1  4  3.690646  30.   4.143754    4
        22  2  4  3.716223  30.   4.131503    4
        23  3  4  3.741757  30.   4.119106    4
        24  3  7   &X24      30.   &Z24 4
        25  2  7   &X25      30.   &Z25 4
        26  1  7   &X26      30.   &Z26 4
 SLINES 21,19,20,23
 SLINES 21,22,23,24,25,26,21
 IJGRID 2
 IJPOINT 29   1  1  3.525998    60.0     3.867997    4
        30  3  1  3.563346    60.0     3.814658    4
 IJPOINT 31  1  4   3.690646  60.   4.143754    4
        32  2  4   3.716223  60.   4.131503    4
        33  3  4   3.741757  60.   4.119106    4
        34  3  7   3.878649  60.   4.243695    4
        35  2  7   3.863789  60.   4.263800    4
        36  1  7   3.848908  60.   4.283832    4
 SLINES 31,29,30,33
 SLINES 31,32,33,34,35,36,31
 RULE 6 1 2
 IJSHELL 34 36 2M.025 2MO. 1 FSH 0 0 0 0. EDGE
 IJSOLID 29,34,1,HSO 0 MSHC
 IJSOLID 30,35,1,HSO 0 MSHC,PRES
MESH
  MERGE
REMARK '
REMARK ' MESH D - MESH OF PART BEING INTERSECTED - MESH 10
REMARK ' ****************************************
 DEFSYS 10,1,8.59 -6.24 4.182926,8.59 -5.24 >
 4.182926,8.59 -6.24 5.182926
  MSYS 10
  let &delz = -2.
  IJPOINT 1  1  1  4.279954   0.   2.590498    4
          2  2  1  .91 15. -70. 2 1,2
          3  5  1  1.2 42. -70. 2 1
          4  7  1  1.4 53. -70. 2 1
          5  9  1  .92 53. -15. 2 1
          6  13 1  .92 53. 60. 2 1
          7  15 1  .92 35 70. 2 1,2
          8  18 1  .92 15. 90. 2 1,2
          9  19 1  3.716223  0.   4.131503    4
          10 19 4  3.905653    0.0      4.787814    4
          11 19 14 8.649978    0.0      4.182927    4
```

```
          12 14 14 2.512 179.99 &delz 10
          13 14 8  2.512  60. &delz 10
          14 6  8  2.512 -100. &delz 10
          15 6  12 2.512 -179.99 &delz 10
          16 1  12 8.649978      0.0      4.182925    4
          17 1  4  4.704024      0.0      2.324177    4
          18 0 0 6.240000     0.0     4.182926    4
          19 0 0 0.0001 0.0 &delz 10
 SLINE 1 2
 SINT 2,3,.33333
 SINT 3,4
 PLINE 4,5,6
 SINT 6,7
 SINT 7,8,2.0
 SLINE 8,9,10
 CIRCLE 10,11,18
 SLINE 11,12
 CIRCLE 12,13,19
        13,14,19
        14,15,19
 SLINE 15,16
 CIRCLE 16,17,18
 SLINE 17,1
 KSSHELL 1 11 1 4M.05 4M0. 1 FSH
 MESH 3
  MERGE TYPE=FSH
REMARK '***************************************************
REMARK 'MESH 11 - CYLINDRICAL SHELL
REMARK '***************************************************
 DEFSYS 11,1,8.59 -6.24 4.24,8.59 -5.24 >
 4.24,8.59 -6.24 5.24
 IJPOINT  1 1  1 2.512 179.99 &delz 10
          2 7 1  2.512  60. &delz 10
          3 15  1  2.512 -100. &delz 10
          4 19  1 2.512 -179.99 &delz 10
          9 0 0 0.000 0.0 &DELZ 10
 IJPOINT  21 1  4 2.6 179.99 0.78 11
          22 7  4  2.6  60.  0.78 11
          23 15  4  2.6 -100. 0.78 11
          24 19  4 2.6 -179.99 0.78 11
          29 0 0 0.000 0.0 0.78 11
 IJPOINT  31 1  5 2.6 179.999 1.36 11
          32 7  5  2.6  60.  1.36 11
          33 15  5  2.6 -100. 1.36 11
          34 19  5 2.6 -179.999 1.36 11
          39 0 0 0.0 0.0 1.36 11
  CIRCLE 1,2,9 : 2,3,9 : 3,4,9
  CIRCLE 21,22,29 : 22,23,29 : 23,24,29
  CIRCLE 31,32,39 : 32,33,39 : 33,34,39
  SLINES 1,21,31
  SLINES 4,24,34
  KSSHELL 1 34 1 4M.05 4M0. 1 FSH
  MESH 2
  MERGE TYPE=FSH

REMARK ' ****************************************************************
REMARK ' SPACE SHUTTLE MAIN ENGINE HIGH PRESSURE FUEL TURBO PUMP (HPFTP)
REMARK ' SUPPORT STRUCTURE MESH
REMARK ' ****************************************************************
```

```
DEFSYS 1 1 3M0.0, 1.0,0.0,0.0 0.0,1.0,0.0     #CYLINDRICAL COORD SYSTEM

REMARK ' *********************************************************************
REMARK ' MESH 12 - CIRCULAR FLANGE
REMARK ' *********************************************************************
######################################################################
IJPOINT   1      1      1      3.70      0.0      0.2
          2      2      1      2.84      0.0      0.2
          3      2      2      2.84      0.0      0.78
          4      3      2      2.60      0.0      0.78
          5      3      3      2.60      0.0      1.36
          6      1      3      3.70      0.0      1.36
SLINES 1T6,1
IJSOLID 0 0 1 HSO
PRISM 19 0.,0.,0. 3 360.

KNAME 6 6 19 19 FLNG NOD9
KNAME 6 6 3 3 FLNG ND10
KNAME 6 6 5 5 FLNG ND11
KNAME 6 6 14 14 FLNG NOD5
KNAME 6 6 15 15 FLNG NOD6
KNAME 6 6 16 16 FLNG NOD7
KNAME 6 6 17 17 FLNG NOD8
MESH 0 1
ROTATE -10. 3
ROTATE 90. 2
TRANS -6.24 2
TRANS 8.59 1
TRANS 4.24 3
MERGE/PRI mesh=%ipp(9)
merge/pri type=Fsh

REMARK ' *********************************************************************
REMARK ' MESH 13 - SUPPORT STRUCTURE BASE
REMARK ' *********************************************************************

######################################################################
IJPOINT   1      1      1     10.86      0.0      -2.811
         11      2      1     10.45     -2.54     -2.811
          2      4      1      9.76     -6.65     -2.811
          3      7      1      3.57    -10.15     -2.811
          4      9      1      0.00    -10.15     -2.811
          5      9      2      9.825   -90.0      -2.811    1
          6      1      2      9.825     6.0      -2.811    1
        100      0      0      0.0       0.0      -2.811

SLINES 1,2,3,4,5
CIRCLE 5,6,100
SLINE 6,1
SLINES

IJSOLID 0 0 1 HSO
PRISM 3  0.,0.,1.23
KNAME 11 11 3 3 BASE NOD1
KNAME 2 2 3 3 BASE NOD2
KNAME 3 3 3 3 BASE NOD3
KNAME 4 4 3 3 BASE NOD4
MESH
assign tolx=.002
merge mesh=3
```

```
SET SYNTAX ON
REMARK ' ****************************************************************
REMARK ' MESH 14 - SHELL ELEMENTS BETWEEN MESH 12 AND 13
REMARK ' ****************************************************************
#####################################################################
#
#   S U B R O U T I N E   X Y Z 1   -   Author K. V. Pool   April, 1987
#
#    SUBROUTINE XYZ1 RETURNS THE X,Y AND Z COORDINATES
#    OF THE FIRST ELEMENT IN THE NODLIST &NLST IN
#    THE VARIABLES &XX,&YY, AND &ZZ.  THESE X, Y AND Z COORDINATES CAN BE
#
#    THIS SUBROUTINE CAN BE USED TO CREATE NEW IJPOINTS THAT HAVE COORDINATES
#    IDENTICAL TO EXISTING NODAL POINTS SO THAT NEW MESHES CAN BE GENERATED
#    THAT ARE BASED ON PREVIOUS MESHES THAT HAVE SINCE BEEN ROTATED AND
#    AND/OR TRANSLATED TO NEW POSITIONS.
#
#    AS AN EXAMPLE OF THE USAGE SEE [KPOOL.SSME.HPFTP]HPFTP-SS.MSH
#*********************************************************************************
#*********************************************************************************


#
     SUB XYZ1 &NLST,&XX,&YY,&ZZ,&IPRT
#
#
#    &IPRT = PRINT CONTROL
#          = 0 FOR NORMAL PRINT
#          = 1 FOR EXTENDED PRINT
#
REMARK '
REMARK ' *****************************************
REMARK '       SUBROUTINE XYZ1 HAS BEEN CALLED
;10 FORMAT '(5X,' NODE LIST NUMBER =',I5)
     WRITE 6 ;10 &NLST
#
#    GET THE NODE LIST FILE
#
     LET &IFN=%IFL(NLST.NV,0,&NLST) # FIND DATABASE FILE NUMBER OF NODE LIST
#
#    CHECK FOR IMPROPER NODE LIST (IFN=0)
     IF &IFN 1,;ERR1,1
     LET &LN=%LFM(&IFN,1) # LOCK FILE IN BLANK COMMON AND
#                           RETURN ADDRESS IN &LN
     LET &NODE=%IBC1(&LN,1) # RETRIEVE NUMBER OF FIRST NODE IN LIST
     LET &XX=%XN(&NODE,1)
     LET &YY=%XN(&NODE,2)
     LET &ZZ=%XN(&NODE,3)
REMARK ' *****************************************
     IF &IPRT 1,;SKIP,1
;200 FORMAT '(5X,'   NODE NUMBER =',I6)
     WRITE 6 ;200 &NODE
REMARK '        X-COORD  Y-COORD  Z-COORD
;201 FORMAT '(5X,3F9.3)
     WRITE 6 ;201 &XX,&YY,&ZZ
REMARK ' *****************************************
;SKIP NOP
     RETURN
;ERR1 REMARK 'IMPROPER NODE LIST REFERENCED
```

```
;400 FORMAT '(5X,' NODE LIST =',I5)
     WRITE 6 ;400 &NLST
     RETURN
     END
#
##########################################################################
NLIST 1 INSERT NAME=BASE,NOD1
NLIST 2 INSERT NAME=BASE,NOD2
NLIST 3 INSERT NAME=BASE,NOD3
NLIST 4 INSERT NAME=BASE,NOD4
NLIST 5 INSERT NAME=FLNG,NOD5
NLIST 6 INSERT NAME=FLNG,NOD6
NLIST 7 INSERT NAME=FLNG,NOD7
NLIST 8 INSERT NAME=FLNG,NOD8
NLIST 9 INSERT NAME=FLNG,NOD9
NLIST 10 INSERT NAME=FLNG,ND10
NLIST 11 INSERT NAME=FLNG,ND11

     CALL XYZ1 1 &XX &YY &ZZ 1
IJPOINT 1   1    1  &XX,&YY,&ZZ

     CALL XYZ1 2 &XX &YY &ZZ 1
IJPOINT 2   3    1  &XX,&YY,&ZZ
IJPOINT 102 4    1  &XX,&YY,&ZZ

     CALL XYZ1 3 &XX &YY &ZZ 1
IJPOINT 3   7    1  &XX,&YY,&ZZ

     CALL XYZ1 4 &XX &YY &ZZ 1
IJPOINT 4   9    1  &XX,&YY,&ZZ

     CALL XYZ1 5 &XX &YY &ZZ 1
IJPOINT 5   9    4  &XX,&YY,&ZZ

     CALL XYZ1 6 &XX &YY &ZZ 1
IJPOINT 6   8    4  &XX,&YY,&ZZ

     CALL XYZ1 7 &XX &YY &ZZ 1
IJPOINT 7   7    4  &XX,&YY,&ZZ

     CALL XYZ1 8 &XX &YY &ZZ 1
IJPOINT 8   6    4  &XX,&YY,&ZZ
IJPOINT 108 5    4  &XX,&YY,&ZZ
IJPOINT 208 4    4  &XX,&YY,&ZZ

     CALL XYZ1 9 &XX &YY &ZZ 1
IJPOINT 9   3    4  &XX,&YY,&ZZ

     CALL XYZ1 10 &XX &YY &ZZ 1
IJPOINT 10   2    4  &XX,&YY,&ZZ

     CALL XYZ1 11 &XX &YY &ZZ 1
IJPOINT 11   1    4  &XX,&YY,&ZZ

SLINES 1,2,102,3,4,5,6,7,8,108,208,9,10,11,1
SLINES 102 208:3,7

KSSHELL 1  5  1 .5 .5 .5 .5 0.0 0.0 0.0 0.0 1 FSH 0 -1
MESH 2
```

```
mset 99,copy,type=HSO
mset 99,delete,mesh=1t6
MERGE mset=99

REMARK '
  NSET 11,COPY,NAME=OUTR,VANE
  NSET 11,INSERT,NAME=INSD,VANE
  MSET 11,COPY,NSET=11
REMARK '
REMARK ' 15 VANE MESHES - MESHES 15 THRU 29 (CLOCKWISE FROM 0 DEGREES)
REMARK ' **************
REMARK ' **************
  DEFSYS 1 1 3M0.0, 1.0,0.0,0.0 0.0,1.0,0.0    #CYLINDRICAL COORD SYSTEM
  IJPOINT 1 1 2 3.230719    12.0          3.461722    1
          2 3 2 2.726711    24.0          3.030447    1
          3 5 2 2.324505    36.0          2.503693    1
  IJPOINT 4 1 8 3.888425    12.0          2.579901    1
          5 3 8 3.438335    24.0          2.194444    1
          6 5 8 3.171350    36.0          1.664181    1
#########################################################################
  IJPOINT 7  1 1 3.184       12.0          3.529       1
          8  3 1 2.638       24.0          3.143       1
          9  5 1 2.277       36.0          2.532       1
  IJPOINT 10 1 9 3.967       12.0          2.512       1
          11 3 9 3.575       24.0          2.108       1
          12 5 9 3.267       36.0          1.666       1
          13 1 3
          14 3 3
          15 5 3
          16 1 7
          17 3 7
          18 5 7

  SLINE 7,8,9,3,6,12,11,10,4,1,7:8,2,5,11:1,2,3:4,5,6
  KSSHELL 7 2 1 .052 .214 .590 .428 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 8 3 1  .214 .052 .428 .590 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 1 14 1 .428 .590 .214 .052 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 2 15 1 .590 .428 .052 .214 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 13 17 1 .052 .214 .214 .052 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 14 18 1  .214 .052 .052 .214 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 16  5 1 .052 .214 .590 .428 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 17  6 1 .214 .052 .428 .590 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 4 11 1 .428 .590 .214 .052 4M0. 1 FSH 0 0 0 0. VANE
  KSSHELL 5 12 1 .590 .428 .052 .214  4M0. 1 FSH 0 0 0 0. VANE
  MESH
  ROTATE -90. 3
  mirror 1
  ASSIGN TOLX=.002
  MERGE MSET=11
  MSET 80,COPY,MESH=%IPP(9)
  LET &ANG = 24.
  DO ;END3 &I = 1 14
  DITTO MSET=80
  ROTATE  &ANG 3
  MERGE MSET=11
  LET &ANG = &ANG + 24.
  ;END3 CONTINUE
  ASSIGN TOLX=.001
  MSET 22,COPY,NAME=VANE
  MSET 33,COPY,NAME=EDGE
```

```
# ELTNAME QUAD,,,,,VOLUME,0.,10000.,89.,181.,-1000.,1000.,4
REMARK ' ******************************************************************
REMARK ' SUPPRESSIONS
REMARK ' ******************************************************************
  DOFSUP 0 NAME=OUTR,BOLT
  DOFLOOS
  FINISH
  STOP
$ BAND
  START -1
  REGPS
  BAND
  STOP
$SETUP
  START -1
  SETUP
  STOP
$MATL
  START -1
  #
  REMARK ' MATL #1 - TITANIUM 5Al - 2.5Sn ELI - MESH 1,2,3,4
  MATISO 1 .155E8 .35 3.E-6 0.
  DENSITY 1 4.2E-4   #.162/386.088
  #
  #
  MATL
  STOP
$LOAD
  START -1
  SET SYNTAX ON
  SET ECHO ON
  LCLEAR 1
  PSURF  1. 1 1 NAME=,,SHLL,PRES
  PSURF  1. 1 1 MESH=7
  PSURF  1. 1 1 MESH=10
  PSURF -1. 1 -1 MESH=11
  PSURF -1. 1 5 NAME=,,INNR,PRES
  PSURF -1. 1 1 NAME=,,OUTR,PRES
  PSURF -1. 1 1 NAME=MSHB,PRES
  PSURF -1. 1 4 NAME=MSHC,PRES
  PSURF -1. 1 1 NAME=MSH5,,,PRES
  PSURF -1. 1 1 NAME=MSH4,,,PRES
LCLEAR 2

REMARK ' MESH 1 NEW LOADS

  MSET 1 COPY MESH 1
  NSET 1 COPY NAME P208,FAC1
  MSET 1 MASK NSET 1
  MSET 1 DELE ELEM 11T1403B48
  MSET 1 DELE ELEM 12T1404B48
  PSURF -208. 1 1 MSET 1

  MSET 2 COPY MESH 1
  NSET 2 COPY NAME P208,FAC2
  MSET 2 MASK NSET 2
  MSET 2 DELE ELEM 11T1403B48
  MSET 2 DELE ELEM 12T1404B48
  PSURF -208. 1 2 MSET 2
```

```
  MSET 4 COPY MESH 1
  NSET 4 COPY NAME P208,FAC4
  MSET 4 MASK NSET 4
  MSET 4 DELE ELEM 11T1403B48
  MSET 4 DELE ELEM 12T1404B48
  PSURF -208. 1 4 MSET 4
#
REMARK ' MESH 2 NEW LOADS

  MSET 1 COPY MESH 2
  NSET 1 COPY NAME P208,FAC1
  MSET 1 MASK NSET 1
  MSET 1 DELE ELEM 1464T3784B80
  MSET 1 DELE ELEM 1476T3796B80
  PSURF -208. 1 1 MSET 1

  MSET 4 COPY MESH 2
  NSET 4 COPY NAME P208,FAC4
  MSET 4 MASK NSET 4
  MSET 4 DELE ELEM 1464T3784B80
  MSET 4 DELE ELEM 1476T3796B80
  PSURF -208. 1 4 MSET 4

  MSET 5 COPY MESH 2
  NSET 5 COPY NAME P208,FAC5
  MSET 5 MASK NSET 5
  MSET 5 DELE ELEM 1464T3784B80
  MSET 5 DELE ELEM 1476T3796B80
  PSURF -208. 1 5 MSET 5

  MSET 1 COPY MESH 2
  NSET 1 COPY NAME P438,FAC1
  MSET 1 MASK NSET 1
  MSET 1 DELE ELEM 1490T3810B80
  MSET 1 DELE ELEM 1504T3824B80
  PSURF -1438. 1 1 MSET 1

  MSET 5 COPY MESH 2
  NSET 5 COPY NAME P438,FAC5
  MSET 5 MASK NSET 5
  MSET 5 DELE ELEM 1490T3810B80
  MSET 5 DELE ELEM 1504T3824B80
  PSURF -1438. 1 5 MSET 5

  MSET 1 COPY ELEM 1507T3827B80
  PSURF -1488. 1 1 MSET 1                    #1488 PSI

  MSET 1 COPY ELEM 1508T3828B80
  PSURF -1546. 1 1 MSET 1                    #1546 PSI

  MSET 1 COPY ELEM 1509T3829B80
  PSURF -1604. 1 1 MSET 1                    #1604 PSI

  MSET 1 COPY ELEM 1510T3830B80
  PSURF -1662. 1 1 MSET 1                    #1662 PSI


  MSET 2 COPY ELEM 1502T3822B80
  PSURF -1721. 1 2 MSET 2                    #1721 PSI
```

```
  MSET 2 COPY ELEM 1495T3815B80
  PSURF -1777. 1 2 MSET 2                    #1777 PSI

  MSET 5 COPY MESH 2
  NSET 5 COPY NAME P777,FAC5
  MSET 5 MASK NSET 5
  PSURF -1777. 1 5 MSET 5

REMARK ' MESH 3 NEW LOADS

  MSET 5 COPY MESH 3
  NSET 5 COPY NAME P777,FAC5
  MSET 5 MASK NSET 5
  MSET 5 DELE ELEM 3841T4914B37
  PSURF -1777. 1 5 MSET 5

  MSET 4 COPY MESH 3
  NSET 4 COPY NAME P500,FAC4
  MSET 4 MASK NSET 4
  PSURF -500. 1 4 MSET 4

  MSET 5 COPY MESH 3
  NSET 5 COPY NAME P500,FAC5
  MSET 5 MASK NSET 5
  PSURF -500. 1 5 MSET 5

  MSET 5 COPY MESH 3
  NSET 5 COPY NAME P19K,FAC5
  MSET 5 MASK NSET 5
  MSET 5 DELE ELEM 3869T4942B37
  MSET 5 DELE ELEM 3871T4944B37
  PSURF -19069. 1 5 MSET 5

REMARK ' POINT LOADS

  P 272.3 3 NAME INNR,BOLT

  MSET 4 COPY MESH 3
  NSET 4 COPY NAME P334,FAC4       #DIFFUSER PILOT LOAD 51,424 LBS/2PI*R*H +500 PSI
  MSET 4 MASK NSET 4
  PSURF -3349. 1 4 MSET 4          #R=6.247499  H=.46 IN. (SEE IJPOINT 57,58 ABOVE)

  LOAD
  STOP
$ SOLVE
  START -1
  SET ECHO ON
  LOADS 1 303.0
  LOADS 2 1.0
  ASSIGN IMPR=1
  SAVE R
  SAVE D
  SAVE S
  SAVE EF
  FILE K [4]KE
  FILE KG [4]KG
  FILE KI [4]KI
  SOLVE 0
  TOC
```

```
  STOP
$SCOPE
START 200000
META OPEN
DEVICE OPEN QMS
SET ECHO ON
TITLE
CATT NUMB SIZE .1
CATT TITL SIZE .3
CATT TEXT SIZE .25
TITLE1 'HPFTP - INLET HOUSING GLOBAL MODEL - VANES
GEOM HIDE
LABEL ON ELEM
PLOT MESH 15T29
STOP
$ UTILITY PROCESSOR
START -1
OPEN 8 'BCD1
BCDOUT/UNFORMAT=VAX 8 MATL.EV
BCDOUT/UNFORMAT=VAX       8 ELEM.EV
BCDOUT/UNFORMAT=VAX       8 INTO.EV
BCDOUT/UNFORMAT=VAX       8 X.NV
BCDOUT/UNFORMAT=VAX       8 NORM.NV
BCDOUT/UNFORMAT=VAX       8 ROT.NV
BCDOUT/UNFORMAT=VAX       8 SKEW.NV
BCDOUT/UNFORMAT=VAX       8 DOF.NV
BCDOUT/UNFORMAT=VAX       8 NAME.NV
BCDOUT/UNFORMAT=VAX       8 NAME.EV
BCDOUT/UNFORMAT=VAX       8 IR.NV
BCDOUT/UNFORMAT=VAX       8 IER.NV
BCDOUT/UNFORMAT=VAX       8 LCS.NV
BCDOUT/UNFORMAT=VAX       8 PCT.HED.MESH
BCDOUT/UNFORMAT=VAX       8 MESH.HED 0 ?
BCDOUT/UNFORMAT=VAX       8 CON.RM.DIR
BCDOUT/UNFORMAT=VAX       8 CON.CON 0 ?
BCDOUT/UNFORMAT=VAX       8 UL.SV 0 ?
BCDOUT/UNFORMAT=VAX       8 EDF.NV 0 0
BCDOUT/UNFORMAT=VAX       8 SDF.NV 0 0
BCDOUT/UNFORMAT=VAX       8 STLT.RM.DIR
BCDOUT/UNFORMAT=VAX       8 D.SV 0 1
BCDOUT/UNFORMAT=VAX       8 S.EIP 0 1
BCDOUT/UNFORMAT=VAX       8 EF.SEV 0 ?
BCDOUT/UNFORMAT=VAX       8 UT.NV 0 ?
BCDOUT/UNFORMAT=VAX       8 HEAD.COM 0 ?
BCDOUT/UNFORMAT=VAX       8 POLY.EV 0 ?
BCDOUT/UNFORMAT=VAX       8 POLY.RM 0 ?
BCDOUT/UNFORMAT=VAX       8 EDGE.RM 0 ?
BCDOUT/UNFORMAT=VAX       8 EDGE.EV 0 ?
BCDOUT/UNFORMAT=VAX       8 SYS.CRM
TOC
STOP
/EOF
```

Appendix B

FINAL HPFTP INLET HOUSING DETAILED VANE SUBMODEL DIAL FINITE ELEMENT MODEL RUNSTREAM

```
JOB,JN=VANE2,T=300,MFL=1500000,US=670535.
ACCOUNT,AC=3,UPW=.
FETCH,DN=MESH,DF=TR,TEXT='DIAL$CRAY:MESH.CEX'.
FETCH,DN=BAND,DF=TR,TEXT='DIAL$CRAY:BAND.CEX'.
FETCH,DN=SETUP,DF=TR,TEXT='DIAL$CRAY:SETUP.CEX'.
FETCH,DN=UTILITY,DF=TR,TEXT='DIAL$CRAY:UTILITY.CEX'.
MESH.
BAND.
SETUP.
UTILITY.
DISPOSE,DN=FT08,DF=BB,TEXT='VANE2.U08'.
BAD.
EXIT.
DISPOSE,DF=TR,DN=FIL002,TEXT='VANE2.FL2'.
/EOF
$SD VANE
$AS VANE2.FL2 FIL002
$AS VANE2MESH.OUT FOR006
$RUN USER$DISK2:[DIAL.EXEL3D2]MESH
CLEAR 200000
MAX/MXPO=2000    10000 2500
ELTYPE 4,2,6
#-------------------------------------------------------------------
#    DETAILED VANE MODEL WITH TORUS OF SSME HPFTP
#-------------------------------------------------------------------
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 1  R=1.86 -----
DEFSYS 1 3 _PT1=2MO. 4.903 _PT2=10. 0. 4.903 _PT3=0. 10. 4.903 _R=2.055
DEFSUR 1 1 1 _R=1.86
        58  1 1    1.954
        59  1 1    2.048
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 2  R=3.037 ----
DEFSYS 2 3 _PT1=2MO. .935 _PT2=10. 0. .935 _PT3=0. 10. .935 _R=4.925
DEFSUR 2 2 1 _R=3.037
        68 2 1    2.943
        69 2 1    2.849
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 3  PHI=35 ----
DEFSYS 3 3 2MO. 1.3990682 10. 0. 1.3990682  0. 10. 1.3990682
DEFSUR 3 3 3 _PHI=35.
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 4  PHI=42.8012089
DEFSYS 4 3 2MO. .7196471 10. 0. .7196471 0. 10. .7196471
DEFSUR 4 4 3 _PHI=42.8012089
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 5  R=.5 ----
DEFSYS 5 3 2MO. 2.8958631 10. 0. 2.8958631 0. 10. 2.8958631 _R=1.85
DEFSUR 5 5 1 _R=.5
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 6  R=3.147 ----
DEFSYS 6 3 _PT1=2MO. .935 _PT2=10. 0. .935 _PT3=0. 10. .935 _R=4.925
DEFSUR 6 6 1 _R=3.147
#----------------------------------------------------------------------
#-- CONVEX SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 7  R=1.3 ----
#DEFSYS 7 3 _PT1=2MO. 1.394 _PT2=10. 0. 1.394 _PT3=0. 10. 1.394 _R=4.421
DEFSYS 7 3 2MO. 1.3827953 10. 0. 1.3827953 0. 10. 1.3827953 _R=4.421
DEFSUR 7  7 1 _R=1.3
        78 7 1    1.372
        79 7 1    1.444
#-- CONVEX SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 8  R=1.5805887 --
DEFSYS 8 3 _PT1=2MO. 1.247 _PT2=10. 0. 1.247 _PT3=0. 10. 1.247 _R=4.66
DEFSUR 8  8 1 _R=1.5805887
        88 8 1    1.6525887
        89 8 1    1.7245887
#-- CONVEX SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 9  PHI=45 ---
```

```
DEFSYS 9 3 _PT1=2MO. -1.612 _PT2=10. 0. -1.612 _PT3=0. 10. -1.612
DEFSUR 9 9 3 _PHI=45.
#-- CONVEX SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 10 PHI=75. ---
DEFSYS 10 3 2MO. -10.8824664 10. 0. -10.8824664 0. 10. -10.8824664
DEFSUR 10 10 3 _PHI=75.
#-- CONCAVE SURFACE TOROIDAL SYSTEM AND CONSTRAINT SURFACE 90 PHI=-35.1303336 -
DEFSYS 90 3 2MO. 8.8960272 10. 0. 8.8960272 0. 10. 8.8960272
DEFSUR 90 90 3 _PHI=-54.9592082
#-- CONCAVE SURFACE CYLINDRICAL SYSTEM AND CONSTRAINT SURFACE 91 R=2.030 --
DEFSYS 91 1 3MO. 10. 0. 0. 0. 10. 0.
DEFSUR 91 91 1 _R=2.030
#-- CONCAVE SURFACE CARTESIAN SYSTEM AND CONSTRAINT SURFACE 92 Z=1.97 -----
DEFSUR 92 0 3 _Z=1.97
#-- CONVEX SURFACE CYLINDRICAL SYSTEM AND CONSTRAINT SURFACE 93 R=4.155 --
DEFSUR 93 91 1 _R=4.155
#-- CONCAVE SURFACE CARTESIAN SYSTEM AND CONSTRAINT SURFACE 94 Z=1.34 -----
DEFSUR 94 0 3 _Z=1.34
#-- CONVEX SURFACE CYLINDRICAL SYSTEM AND CONSTRAINT SURFACE 95 R=4.195 --
DEFSUR 95 91 1 _R=4.195
#-- CONCAVE SURFACE CARTESIAN SYSTEM AND CONSTRAINT SURFACE 96 Z=2.543 -----
DEFSUR 96 0 3 _Z=2.543
#-----------------------------------------------------------------------
#-- VANE ----------------------------------------------------------------
#-- SECTION Z-Z CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 11  R=.026 ----
DEFSYS 11 1 3.3140034 .6308132 3.3181209 3.3140034 0. 3.3181209>
            4.0211101 .6308132 4.0252277
DEFSUR 21 11 1 _r=.026
       31 11 1 _r=.07
       41 11 1 _r=.214
#-- SECTION Z-Z CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 12  R=2. ----
DEFSYS 12 1 1.9884341 1.249205 1.9925517 1.9884341 0. 1.9925517>
            2.6955409 1.249205 2.6996589
DEFSUR 22 12 1 _r=2.
       32 12 1 _r=2.044
       42 12 1 _r=2.188
#-- SECTION Z-Z CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 13  R=3.471 -
DEFSYS 13 1 1.1739069 2.1640446 1.1780244 1.1739069 0. 1.1780244>
            1.8810136 2.1640446 1.8851312
DEFSUR 23 13 1 _R=3.471
       33 13 1 _r=3.515
       43 13 1 _r=3.659
#-- SECTION Z-Z CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 14  R=.026 -
DEFSYS 14 1 2.4241186 -.7926370 2.4282361 2.4241186 -1.7926370  2.4282361>
            3.1312254 -.7926370 3.1353429
DEFSUR 24 14 1 _R=.026
       34 14 1 _r=.07
       44 14 1 _r=.214
#-- SECTION Y-Y LOCAL PLANE SYSTEM AND CONSTRAINT SURFACE 15  ----
DEFSYS 15 0 2.9196439 0. 2.9237614 1.9196439 -1.5995893 1.9237614>
            3.9196439 0. 1.9237614
DEFSUR 15 15 3 _z=0.
       25 15 3 _z=-.026
       35 15 3 _z=-.07
       45 15 3 _z=-.214
       55 15 3 _z=-.0525
       65 15 3 _z=-.17
#----------------------------------------------------------------
#-- SECTION Y-Y LOCAL PLANE SYSTEM AND CONSTRAINT SURFACE 16  R=.026 --
DEFSYS 16 1 3.7453632 .5086961 2.7340754 3.7453632 0. 2.7340754>
            4.4524700 .5086961 3.4411822
```

```
DEFSUR 26 16 1 _r=.026
       36 16 1 _r=.0525
       46 16 1 _r=.17
#-- SECTION Y-Y CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 12  R=2. ----
DEFSYS 17 1 2.4282407 1.1621884 1.4169529 2.4282407 0. 1.4169529>
            3.1353475 1.1621884 2.1240597
DEFSUR 27 17 1 _r=2.
       37 17 1 _r=2.0265
       47 17 1 _r=2.144
#-- SECTION Y-Y CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 13  R=3.275 -
DEFSYS 18 1 1.7390335 1.9841446 .7277457 1.7390335 0. .7277457>
            2.4461402 1.9841446 1.4348524
DEFSUR 28 18 1 _R=3.275
       38 18 1 _r=3.3015
       48 18 1 _r=3.419
#-- SECTION Y-Y CYCLINDRICAL SYSTEM AND CONSTRAINT SURFACE 14  R=.026 -
DEFSYS 19 1 2.9318213 -.7926370 1.9205335 2.9318213 -1.7926370 1.9205335>
            3.6389280 -.7926370 2.6276403
DEFSUR 29 19 1 _R=.026
       39 19 1 _r=.0525
       49 19 1 _r=.17
#----------------------------------------------------------------------
#----------------------------------------------------------------------
#---------- MESH 1 - VANE ---------------------------------------------
#----- STATION 1  -  BOUNDARY AT CONCAVE SURFACE SIDE ---
IJPOIN 101  1  1 _R=.214 _THETA=138.5197667 _Z=.320  11   3 15 41
ASSIGN TOLX=0.005
IJPOIN 102  3  1    .214       -140.            .320  11   3  4 41
ASSIGN TOLX=0.001
IJPOIN 103  5  1    .214       -131.4802333     .320  11   4 41 45
IJPOIN 104 13  1 _x=-.2    _y=-.320        _z=-.214   15   4    45
ASSIGN TOLX=0.005
IJPOIN 122 19  1 _x=.3958574   -.320        -.214     15   4  5 45
IJPOIN 123 23  1 _x=.7665687   -.320        -.214     15   5  6 45
ASSIGN TOLX=0.001
IJPOIN 105 25  1 _r=.214       -131.4802333     .320  14   6 44 45
       106 29  1    .214        -41.4802333     .320  14   6 15 44
       107 29  3 _x=1.058    -.320              0.    15   5 15
ASSIGN TOLX=0.005
IJPOIN 108 29  5    .214        -41.4802333     .320  14   6 15 44
IJPOIN 109 27  5    .214         -5.5           .320  14   5  6 44
IJPOIN 110 25  5    .214         30.8790069     .320  14   5 43 44
ASSIGN TOLX=0.001
IJPOIN 124 23  5   3.659         34.0043818     .320  13   4  5 43
IJPOIN 125 17  5   3.659         43.            .320  13   4    43
ASSIGN TOLX=0.001
IJPOIN 111 13  5   3.659         51.5437539     .320  13   4 42 43
       112 11  5   2.188         54.9443595     .320  12   3  4 42
IJPOIN 113  5  5   2.188         69.3596831     .320  12   3    42
IJPOIN 114  3  5   2.188         71.7436894     .320  12   3 41 42
IJPOIN 115  1  5   ..214        138.5197667     .320  11   3 15 41
       116  1  3 _x=-.842    -.320              0.    15   3 15
       117  3  3 _x=-.842    -.320              0.    15   3 15
       118  5  3 _x=-.842    -.320              0.    15   3 15
       119 13  3 _x=-.2      -.320              0.    15   4 15
       120 25  3 _x=1.058    -.320              0.    15   5 15
       121 27  3 _x=1.058    -.320              0.    15   5 15
#----- STATION 2  -  INTERSECTION OF THE VANE AND CONCAVE SURFACE ---
ASSIGN TOLX=0.005
IJPOIN 201  1  1 _R=.214 _THETA=138.5197667 _Z=.175  11   1 15 41
```

```
IJPOIN 202  3  1     .214        -150.3004833     .175  11    1  2 41
ASSIGN TOLX=0.001
IJPOIN 203  5  1     .214        -131.4802333     .175  11    2 41 45
       204 13  1 _x=-.2    _y=-.175        _z=-.214     15    2    45
IJPOIN 222 19  1 _x=.3958574   -.175          -.214     15    2    45
IJPOIN 223 23  1 _x=.7665687   -.175          -.214     15    2    45
       205 25  1 _r=.214       -131.4802333   .175      14    2 44 45
       206 29  1     .214        -41.4802333  .175      14    2    44
       207 29  3 _x=1.058    -.175            0.        15    2 15
       208 29  5     .214        -41.4802333  .175      14    2    44
       209 27  5     .214         -5.5        .175      14    2    44
       210 25  5     .214         30.8790069  .175      14    2 43 44
       224 23  5   3.659          35.         .175      13    2 43
       225 17  5   3.659          45.         .175      13    2 43
ASSIGN TOLX=0.005
IJPOIN 211 13  5   3.659          51.5437539  .175      13    2 42 43
       212 11  5   2.188          53.9324362  .175      12    1  2 42
ASSIGN TOLX=0.001
IJPOIN 213  5  5   2.188          69.3596831  .175      12    1    42
IJPOIN 214  3  5   2.188          71.7436894  .175      12    1 41 42
IJPOIN 215  1  5     .214        138.5197667  .175      11    1 15 41
       216  1  3 _x=-.842    -.175               0.        15    1 15
       217  3  3 _x=-.842    -.175               0.        15    1 15
       218  5  3 _x=-.842    -.175               0.        15    1 15
       219 13  3 _x=-.2      -.175               0.        15    2 15
       220 25  3 _x=1.058    -.175               0.        15    2 15
       221 27  3 _x=1.058    -.175               0.        15    2 15
#----- STATION 3  -  FILLET OF THE VANE AND CONCAVE SURFACE ---
IJPOIN 301  1  1 _R=.120 _THETA=138.5197667 _Z=.090 11    58 15 31
ASSIGN TOLX=0.005
IJPOIN 302  3  1     .120        -150.3004833     .090  11    58    31
IJPOIN 303  5  1     .120        -131.4802333     .090  11    58 68 35
ASSIGN TOLX=0.001
IJPOIN 304 13  1 _x=-.2    _y=-.090        _z=-.120     15    68    35
       305 25  1 _r=.120       -131.4802333   .090      14    68 34 35
       306 29  1     .120        -41.4802333  .090      14    68    34
       307 29  3 _x=1.058    -.090            0.        15    68 15
       308 29  5     .120        -41.4802333  .090      14    68    34
       309 27  5     .120         -5.5        .090      14    68    34
       310 25  5     .120         30.8790069  .090      14    68 33 34
ASSIGN TOLX=0.001
IJPOIN 311 13  5   3.515          51.5437539  .090      13    68 32 33
       312 11  5   2.044          59.         .090      12    58 68 32
ASSIGN TOLX=0.001
IJPOIN 313  5  5   2.094          70.9043343  .090      12    58    32
IJPOIN 314  3  5   2.094          71.7436894  .090      12    58 31 32
IJPOIN 315  1  5     .120        138.5197667  .090      11    58 15 31
       316  1  3 _x=-.842    -.090               0.  15    58 15
       317  3  3 _x=-.842    -.090               0.  15    58 15
       318  5  3 _x=-.842    -.090               0.  15    58 15
       319 13  3 _x=-.2      -.090               0.  15    68 15
       320 25  3 _x=1.058    -.090               0.  15    68 15
       321 27  3 _x=1.058    -.090               0.  15    68 15
#----- STATION 4  -  THE VANE SECTION NEAR CONCAVE SURFACE ---
IJPOIN 401  1  1 _R=.026 _THETA=138.5197667 _Z=.009 11    59 15 21
ASSIGN TOLX=0.007
IJPOIN 402  3  1     .026        -150.            .009  11    59    21
IJPOIN 403  5  1     .026        -131.4802333     .009  11    59 69 25
ASSIGN TOLX=0.001
IJPOIN 404 13  1 _x=-.2    _y=-.009        _z=-.026     15    69    25
```

```
        405 25  1 _r=.026         -131.4802333    .009  14    69 24 25
        406 29  1 ¯  .026          -41.4802333    .009  14    69    24
        407 29  3 _x=1.058     -.009             0.     15    69 15
        408 29  5 ¯  .026          -41.4802333    .009  14    69    24
        409 27  5    .026           -5.5          .009  14    69    24
        410 25  5    .026           30.8790069    .009  14    69 23 24
ASSIGN TOLX=0.001
IJPOIN 411 13  5   3.471            51.5437539    .009  13    69 22 23
       412 11  5   2.000            60.           .009  12    59 69 22
ASSIGN TOLX=0.001
IJPOIN 413  5  5   2.000            71.4244601    .009  12    59    22
IJPOIN 414  3  5   2.000            71.7436894    .009  12    59 21 22
IJPOIN 415  1  5    .026           138.5197667    .009  11    59 15 21
       416  1  3 _x=-.842      -.009               0.   15    59 15
       417  3  3 ¯x=-.842      -.009               0.   15    59 15
       418  5  3 ¯x=-.842      -.009               0.   15    59 15
       419 13  3 ¯x=-.2        -.009               0.   15    69 15
       420 25  3 ¯x=1.058      -.009               0.   15    69 15
       421 27  3 ¯x=1.058      -.009               0.   15    69 15
#----- STATION 5 ¯-  THE VANE SECTION NEAR CONVEX SURFACE ---
ASSIGN TOLX=0.001
IJPOIN 501  1  1 _R=.026 _THETA=138.5197667 _Z=-.030  16   79 15 26
IJPOIN 502  3  1 ¯  .026 ¯       -150.          -.030  16   79    26
IJPOIN 503  5  1    .026         -131.4802333   -.030  16   79 26 25
IJPOIN 504 13  1 _x=0.      _y=.748       _z=-.026     15   79    25
ASSIGN TOLX=0.0058
IJPOIN 522 19  1 _x=.6       .748           -.026      15   79 89 25
ASSIGN TOLX=0.001¯
IJPOIN 505 25  1 _r=.026         -131.4802333   -.030  19   89 29 25
       506 29  1 ¯  .026          -41.4802333   -.030  19   89    29
       507 29  3 _x=1.058    .748           0.         15   89 15
       508 29  5 ¯  .026          -41.4802333   -.030  19   89    29
IJPOIN 509 27  5    .026           -5.5         -.030  19   89    29
IJPOIN 510 25  5    .026           30.8790069   -.030  19   89 28 29
ASSIGN TOLX=0.0058
IJPOIN 511 19  5   3.275           36.          -.030  18   79 89 28
ASSIGN TOLX=0.001
IJPOIN 512 13  5   2.000           49.8589617   -.030  17   79 27 28
IJPOIN 513  5  5   2.000           70.3646510   -.030  17   79    27
IJPOIN 514  3  5   2.000           70.6675      -.030  17   79 26 27
IJPOIN 515  1  5    .026          138.5197667   -.030  16   79 15 26
       516  1  3 _x=-.679     .748               0.    15   79 15
       517  3  3 ¯x=-.679     .748               0.    15   79 15
       518  5  3 ¯x=-.679     .748               0.    15   79 15
       519 13  3 ¯x=0.        .748               0.    15   79 15
       520 25  3 ¯x=1.058     .748               0.    15   89 15
       521 27  3 ¯x=1.058     .748               0.    15   89 15
#----- STATION 6 ¯-  FILLET OF THE VANE SECTION AT CONVEX SURFACE ---
IJPOIN 601  1  1 _R=.0525 _THETA=138.5197667 _Z=-.030  16   78 15 36
IJPOIN 602  3  1 ¯  .0525 ¯       -160.         -.030  16   78    36
IJPOIN 603  5  1    .0525        -131.4802333   -.030  16   78 36 55
IJPOIN 604 13  1 _x=0.      _y=.748       _z=-.0525    15   78    55
ASSIGN TOLX=0.0058
IJPOIN 622 19  1 _x=.52      .748           -.0525     15   78 88 55
ASSIGN TOLX=0.001¯
IJPOIN 605 25  1 _r=.0525        -131.4802333   -.030  19   88 39 55
       606 29  1 ¯  .0525         -41.4802333   -.030  19   88 15 39
       607 29  3 _x=1.058    .748           0.         15   88 15
       608 29  5 ¯  .0525         -41.4802333   -.030  19   88 15 39
IJPOIN 609 27  5    .0525          -5.5         -.030  19   88    39
```

```
IJPOIN 610 25  5    .0525          30.8790069    -.030  19    88 38 39
ASSIGN TOLX=0.0058
IJPOIN 611 21  5   3.3015         36.            -.030   18    78 88 38
ASSIGN TOLX=0.001
IJPOIN 612 13  5   2.0525         49.8589617     -.030   17    78 37 38
IJPOIN 613  5  5   2.0525         69.3372175     -.030   17    78    37
IJPOIN 614  3  5   2.0525         70.6675        -.030   17    78 36 37
IJPOIN 615  1  5    .0525         138.5197667     -.030  16    78 15 36
       616  1  3 _x=-.679      .748                 0.     15    78 15
       617  3  3 _x=-.679      .748                 0.     15    78 15
       618  5  3 _x=-.679      .748                 0.     15    78 15
       619 13  3 _x=0.         .748                 0.     15    78 15
       620 25  3 _x=1.058      .748                 0.     15    88 15
       621 27  3 _x=1.058      .748                 0.     15    88 15
#----- STATION 7 -  FILLET OF THE VANE SECTION AT CONVEX SURFACE ---
ASSIGN TOLX=0.001
IJPOIN 701  1  1 _R=.170 _THETA=138.5197667 _Z=-.150  16      7 15 46
IJPOIN 702  3  1    .170        -160.            -.150  16      7    46
IJPOIN 703  5  1    .170        -131.4802333     -.150  16      7 46 65
IJPOIN 722  7  1 _x=-.51   _y=.868         _z=-.150       15      7    65
ASSIGN TOLX=0.001
IJPOIN 704 13  1 _x=0.     _y=.868         _z=-.150       15      7    65
ASSIGN TOLX=0.005705
IJPOIN 723 17  1 _x=.381      .868              -.150     15      7  8 65
IJPOIN 724 19  1 _x=.5        .868              -.150     15      8    65
IJPOIN 705 25  1 _r=.170        -131.4802333     -.150  19      8 49 65
ASSIGN TOLX=0.001
IJPOIN 706 29  1    .170         -41.4802333     -.150  19      8 15 49
       707 29  3 _x=1.058     .868               0.       15      8 15
       708 29  5    .170         -41.4802333     -.150  19      8 15 49
ASSIGN TOLX=0.001
IJPOIN 709 27  5    .170          -5.5           -.150  19      8    49
IJPOIN 710 25  5    .170          30.8790069     -.150  19      8 48 49
IJPOIN 725 23  5   3.419          34.            -.150  18      8    48
ASSIGN TOLX=0.0058
IJPOIN 711 21  5   3.419          35.25              -.150  18     7  8 48
ASSIGN TOLX=0.001
IJPOIN 726 19  5   3.419          40.            -.150  18      7    48
IJPOIN 712 13  5   2.144          49.8589617     -.150  17      7 47 48
IJPOIN 727 11  5   2.144          54.5           -.150  17      7    47
IJPOIN 728  9  5   2.144          59.            -.150  17      7    47
ASSIGN TOLX=0.005
IJPOIN 713  5  5   2.144          68.8300281     -.150  17      7    47
IJPOIN 714  3  5   2.144          70.6675        -.150  17      7 46 47
ASSIGN TOLX=0.001
IJPOIN 715  1  5    .170         138.5197667     -.150  16      7 15 46
       716  1  3 _x=-.679      .868                 0.     15     7 15
       717  3  3 _x=-.679      .868                 0.     15     7 15
       718  5  3 _x=-.679      .868                 0.     15     7 15
       719 13  3 _x=0.         .868                 0.     15     7 15
       720 25  3 _x=1.058      .868                 0.     15     8 15
       721 27  3 _x=1.058      .868                 0.     15     8 15
#----- STATION 8 -  BOUNDARY AT CONVEX SURFACE SIDE ---
ASSIGN TOLX=0.001
IJPOIN 801  1  1 _R=.170 _THETA=138.5197667 _Z=-.425  16      9 15 46
IJPOIN 802  3  1    .170        -160.            -.425  16      9    46
IJPOIN 803  5  1    .170        -131.4802333     -.425  16      9    46
       822  7  1 _x=-.6353931 1.143            -.170      15      9    65
IJPOIN 804 13  1 _x=0.     _y=1.143         _z=-.170      15      9    65
ASSIGN TOLX=.005
```

```
IJPOIN 823 19  1 _x=.5218596 1.143           -.170     15    9 10 65
IJPOIN 805 25  1 _r=.170       -131.4802333    -.425  19    10 49 65
ASSIGN TOLX=0.001
IJPOIN 806 29  1    .170        -41.4802333    -.425  19    10 15 49
       807 29  3 _x=1.058    1.143              0.     15    10 15
       808 29  5    .170        -41.4802333    -.425  19    10 15 49
ASSIGN TOLX=.001
IJPOIN 809 27  5    .170          -5.5          -.425  19    10    49
IJPOIN 810 25  5    .170          30.8790069    -.425  19    10 48 49
ASSIGN TOLX=0.001
IJPOIN 811 23  5   3.419          33.5646343    -.425  18    10  9 48
       824 19  5   3.419          41.           -.425  18     9    48
IJPOIN 812 13  5   2.144          49.8589617    -.425  17     9 47 48
       825 11  5   2.144          52.7420319    -.425  17     9    47
       826  9  5   2.144          58.           -.425  17     9    47
IJPOIN 813  5  5   2.144          68.8300281    -.425  17     9    47
IJPOIN 814  3  5   2.144          70.6675       -.425  17     9 46 47
IJPOIN 815  1  5    .170         138.5197667    -.425  16     9 15 46
       816  1  3 _x=-.679     1.143                0.  15     9 15
       817  3  3 _x=-.679     1.143                0.  15     9 15
       818  5  3 _x=-.679     1.143                0.  15     9 15
       819 13  3 _x=0.        1.143                0.  15     9 15
       820 25  3 _x=1.058     1.143                0.  15    10 15
       821 27  3 _x=1.058     1.143                0.  15    10 15
#------------------------------------------------------------------
SINTER 101 102 : 102 103 : 103 104 :104 122 :122 123 :123 105 :105 106
       106 107 : 107 108 : 108 109 :109 110 :110 124 :124 125 :125 111
       111 112
       112 113 : 113 114 : 114 115 :115 116 :116 101 :118 119 :119 120
SLINES 117 117 : 121 121
#------------------------------------------------------------------
IJGRID 1
SINTER 201 202 : 202 203 : 203 204 : 204 222 :222 223 :223 205
       205 206 : 206 207 : 207 208 : 208 209
       209 210 : 210 224 : 224 225 : 225 211 :211 212 :212 213
       213 214 : 214 215 : 215 216 : 216 201 :218 219 :219 220
SLINES 217 217 : 221 221
#------------------------------------------------------------------
IJGRID 2
SINTER 301 302 : 302 303 : 303 304 : 304 305 : 305 306 : 306 307
       307 308 : 308 309 : 309 310 : 310 311 : 311 312 : 312 313
       313 314 : 314 315 : 315 316 : 316 301 : 318 319 : 319 320
SLINES 317 317 : 321 321
#------------------------------------------------------------------
IJGRID 3
SINTER 401 402 : 402 403 : 403 404 : 404 405 : 405 406 : 406 407
       407 408 : 408 409 : 409 410 : 410 411 : 411 412 : 412 413
       413 414 : 414 415 : 415 416 : 416 401 : 418 419 : 419 420
SLINES 417 417 : 421 421
#------------------------------------------------------------------
IJGRID 4
SINTER 501 502 : 502 503 : 503 504 : 504 522 :522 505 :505 506 :506 507
       507 508 : 508 509 : 509 510 : 510 511 :511 512 :512 513
       513 514 : 514 515 : 515 516 : 516 501 :518 519 :519 520
SLINES 517 517 : 521 521
#------------------------------------------------------------------
IJGRID 5
SINTER 601 602 : 602 603 : 603 604 : 604 622 :622 605 :605 606 :606 607
       607 608 : 608 609 : 609 610 : 610 611 :611 612 :612 613
       613 614 : 614 615 : 615 616 : 616 601 :618 619 :619 620
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SLINES 617 617 : 621 621
#------------------------------------------------------------------
IJGRID 6
SINTER 701 702 : 702 703 : 703 722 : 722 704 : 704 723
       723 724 : 724 705 : 705 706 : 706 707
       707 708 : 708 709 : 709 710 : 710 725 : 725 711 : 711 726
       726 712 : 712 727 : 727 728 : 728 713
       713 714 : 714 715 : 715 716 : 716 701 :718 719 :719 720
SLINES 717 717 : 721 721
#------------------------------------------------------------------
IJGRID 7
SINTER 801 802 : 802 803 : 803 822 : 822 804 : 804 823 : 823 805
       805 806 : 806 807 : 807 808 : 808 809 : 809 810 : 810 811
       811 824 : 824 812 : 812 825 : 825 826 : 826 813
       813 814 : 814 815 : 815 816 : 816 801 : 818 819 : 819 820
SLINES 817 817 : 821 821
IJSOL  0 0 1 SO
RULE   5 1
      13 2 3
      23 4
      31 5 6
      35 7
#------------------------------------------------------------------
#KNAME  119 102  1  1 FACE IN CENT C
#      119 112  1  1 FACE IN CENT C
#       119 122  1  1 FACE IN CENT C
#       119 124  1  1 FACE IN CENT C
#KNAME  819 822 35 35 FACE OUT CENT C
#       819 825 35 35 FACE OUT CENT C
#       819 823 35 35 FACE OUT CENT C
#       819 811 35 35 FACE OUT CENT C
#------------------------------------------------------------------
MESH
MERGE
NSET=1 COPY RANGE=3 19 1
NSET=1 INSE RANGE=32 40 1
NSET=1 INSE RANGE=47 62 1
NSET=1 INSE RANGE=69 76 1
NSET=1 INSE RANGE=88 100 1
NODNAM FACE IN CENT C 0 NSET=1
NSET=2 COPY RANGE=2455 2467 1
NSET=2 INSE RANGE=2481 2487 1
NSET=2 INSE RANGE=2495 2510 1
NSET=2 INSE RANGE=2517 2523 1
NSET=2 INSE RANGE=2536 2548 1
NODNAM FACE OUT CENT C 0 NSET=2
#---------- MESH 2 - CONCAVE  BOTTOM  LEFT ------------------------
#--------- STATION 1 ------------------------------------
IJPOIN 131  1  1   2.030         24.      1.97          91  91 92
       132 23  1   2.030        -30.      1.97          91  91 92
       133 23  3   3.147        -30.    156.9149353      6   6 91
       134 23  5   3.147        -30.    150.             6   6
       106 19  5    .214        -41.4802333     .320   14   6 15 44
IJPOIN 105 15  5 _r=.214       -131.4802333     .320   14   6 44 45
ASSIGN TOLX=0.005
IJPOIN 123 15  7 _x=.7665687   -.320          -.214    15   5  6 45
       135 13  7 _x=.7665687   -.320          -.214    15   5  6 45
IJPOIN 122 13 11 _x=.3958574   -.320          -.214    15   4  5 45
       136 11 11 _x=.3958574   -.320          -.214    15   4  5 45
ASSIGN TOLX=0.001
```

```
IJPOIN 104 11 17 _x=-.2    _y=-.320         _z=-.214     15    4     45
       137  9 17 _x=-.2    _y=-.320         _z=-.214     15    4     45
IJPOIN 103  9 25    .214        -131.4802333     .320    11    4  41 45
       138  7 25    .214        -131.4802333     .320    11    4  41 45
ASSIGN TOLX=0.005
IJPOIN 102  7 27  . .214        -140.     .320           11    3  4  41
IJPOIN 101  7 29 _R=.214 _THETA=138.5197667 _Z=.320      11    3  15 41
ASSIGN TOLX=0.001
IJPOIN 139  7 33 _R=4.3044512 _THATER=12.75  _PHI=35.  3    3  90
ASSIGN TOLX=0.001
IJPOIN 140  1 33 _R=4.3044512 _THATER=24.    _PHI=35.  3    3  90
       141  1 29    3.950          24.          35.    3    3
       142  1 27    3.6725711      24.          35.    3    3  4
IJPOIN 143  1 11    3.2028762      24.     42.8012089  4    4  5
       144  1  7     .5            24.    -32.5248043  5    5  6
       145  1  5    3.147          24     150.         6    6
       146  1  3    3.147          24.    156.9149353  6    6  91
#--------- STATION 2 -----------------------------------
IJPOIN 231  1  1   3.037          24.    160.0745708   2    2  92
       232 23  1   3.037         -30.    160.0745708   2    2  92
       233 23  3   3.037         -30.    156.          2    2
       234 23  5   3.037         -30.    150.          2    2
       206 19  5    .214         -41.4802333     .175  14    2     44
       205 15  5 _r=.214        -131.4802333     .175  14    2  44 45
IJPOIN 223 15  7 _x=.7665687    -.175           -.214  15    2     45
IJPOIN 235 13  7 _x=.7665687    -.175           -.214  15    2     45
IJPOIN 222 13 11 _x=.3958574    -.175           -.214  15    2     45
IJPOIN 236 11 11 _x=.3958574    -.175           -.214  15    2     45
       204 11 17 _x=-.2    _y=-.175         _z=-.214   15    2     45
       237  9 17 _x=-.2    _y=-.175         _z=-.214   15    2     45
IJPOIN 203  9 25    .214        -131.4802333     .175  11    2  41 45
IJPOIN 238  7 25    .214        -131.4802333     .175  11    2  41 45
ASSIGN TOLX=0.005
IJPOIN 202  7 27    .214        -150.3004833     .175  11    1  2  41
IJPOIN 201  7 29 _R=.214 _THETA=138.5197667 _Z=.175    11    1  15 41
ASSIGN TOLX=0.001
IJPOIN 239  7 33 _R=1.86      12.75 _PHI=-35.8105867   1    1  90
IJPOIN 240  1 33 _R=1.86      24.   _PHI=-35.8105867   1    1  90
       241  1 29    1.86      24.       -48.           1    1
       242  1 27    1.86      24.       -54.1233       1    1  2
IJPOIN 243  1 11    3.037     24.       143.           2    2
       244  1  7    3.037     24.       146.           2    2
       245  1  5    3.037     24.       150.           2    2
       246  1  3    3.037     24.       156.           2    2
#------------------------------------------------------------------
SINTER 131 132 : 132 133 : 133 134 :134 106 :106 105 :105 123 :135 122
       136 104 : 137 103 : 138 102 :101 102 :101 139 :139 140
       140 141 : 141 142 : 142 143 :143 144 :144 145 :145 146
       146 131
SLINES 123 135 : 122 136 : 104 137 : 103 138
#------------------------------------------------------------------
IJGRID 1
SINTER 231 232 : 232 233 : 233 234 :234 206 :206 205 :205 223 :235 222
       236 204 : 237 203 : 238 202 :201 202 :201 239 :239 240
       240 241 : 241 242 : 242 243 :243 244 :244 245 :245 246
       246 231
SLINES 223 235 : 222 236 : 204 237 :203 238
IJSOL  0 0 1 SO
RULE   5 1
KNAME  122 142 1 1 FACE IN CENT A
```

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        131 140 1 5 FACE IN LEFT A
        132 134 1 5 FACE IN RIGH A
#-------------          139 140 1 5 FACE IN TOP A    (VANE2.PRF)
MESH
MERGE
ASSIGN TOLX=0.005
MERGE
ASSIGN TOLX=0.001
#---------- MESH 3 - CONCAVE  BOTTOM  RIGHT ----------------------------
#--------- STATION 1 -----------------------------------
IJPOIN 139  1 29  R=4.3044512  THATER=12.75   PHI=35.  3    3 90
IJPOIN 101  1 25 _R=.214 _THETA=138.5197667 _Z=.320  11    3 15 41
IJPOIN 114  3 25   2.188          71.7436894    .320  12    3 41 42
IJPOIN 113  5 25   2.188          69.3596831    .320  12    3    42
       150  5 19   2.188          54.9443595    .320  12    3  4 42
       112  7 19   2.188          54.9443595    .320  12    3  4 42
IJPOIN 151  7 17   3.659          51.5437539    .320  13    4 42 43
IJPOIN 149  9 17   3.659          51.5437539    .320  13    4 42 43
IJPOIN 111 11 17   3.659          51.5437539    .320  13    4 42 43
IJPOIN 152 11 13   3.659          43.           .320  13    4    43
IJPOIN 153 13 13   3.659          43.           .320  13    4    43
IJPOIN 154 13  7   3.659          34.0043818    .320  13    4  5 43
IJPOIN 124 15  7   3.659          34.0043818    .320  13    4  5 43
ASSIGN TOLX=0.005
IJPOIN 155 15  5    .214          30.8790069    .320  14    5 43 44
IJPOIN 110 17  5    .214          30.8790069    .320  14    5 43 44
IJPOIN 109 17  3    .214          -5.5          .320  14    5  6 44
IJPOIN 106 17  1    .214         -41.4802333    .320  14    6 15 44
ASSIGN TOLX=0.001
IJPOIN 134 21  1   3.147         -30.     150.          6    6
IJPOIN 156 21  3    .5           -30.     -32.5248043   5    5  6
IJPOIN 157 21  7    3.2028762    -30.      42.8012089   4    4  5
       158 21 19   3.6725711     -30.         35.       3    3  4
IJPOIN 159 21 29  _R=4.3044512  _THATER=-30.  _PHI=35.  3    3 90
       160  7 29    4.3044512     5.              35.   3    3 90
       161  5 29    4.3044512     7.              35.   3    3 90
       162  3 29    4.3044512     9.              35.   3    3 90
#--------- STATION 2 -----------------------------------
IJPOIN 239  1 29  _R=1.86       12.75   _PHI=-35.1303336  1    1 90
IJPOIN 201  1 25  _R=.214  _THETA=138.5197667 _Z=.175  11    1 15 41
IJPOIN 214  3 25   2.188          71.7436894    .175  12    1 41 42
IJPOIN 213  5 25   2.188          69.3596831    .175  12    1    42
ASSIGN TOLX=0.005
IJPOIN 250  5 19   2.188          53.9324362    .175  12    1  2 42
       212  7 19   2.188          53.9324362    .175  12    1  2 42
IJPOIN 251  7 17   3.659          51.5437539    .175  13    2 42 43
IJPOIN 249  9 17   3.659          51.5437539    .175  13    2 42 43
IJPOIN 211 11 17   3.659          51.5437539    .175  13    2 42 43
IJPOIN 252 11 13   3.659          45.           .175  13    2    43
IJPOIN 253 13 13   3.659          45.           .175  13    2    43
       254 13  7   3.659          35.           .175  13    2 43
       224 15  7   3.659          35.           .175  13    2 43
IJPOIN 255 15  5    .214          30.8790069    .175  14    2 43 44
       210 17  5    .214          30.8790069    .175  14    2 43 44
       209 17  3    .214          -5.5          .175  14    2    44
       206 17  1    .214         -41.4802333    .175  14    2    44
       234 21  1   3.037         -30.      150.          2    2
IJPOIN 256 21  3   3.037         -30.      145           2    2
IJPOIN 257 21  7   3.037         -30.      140.          2    2
       258 21 19    1.86      -30.        -54.1223       1    1  2
```

```
IJPOIN 259 21 29 _R=1.86      -30.          -35.8105867  1    1 90
       260  7 29 _R=1.86        5.          -35.8105867  1    1 90
       261  5 29 _R=1.86        7.          -35.8105867  1    1 90
       262  3 29 _R=1.86        9.          -35.8105867  1    1 90
#-------------------------------------------------------------------
SINTER 139 101 : 101 114 : 114 113 : 113 150 : 112 151 : 111 152
       153 154 : 124 155
       110 109 : 109 106 : 106 134 : 134 156 : 156 157
       157 158 : 158 159 : 159 160 : 160 161 : 161 162 : 162 139
SLINES 150 112 : 151 149 : 149 111 : 152 153 : 154 124 : 155 110
#-------------------------------------------------------------------
IJGRID 1
SINTER 239 201 : 201 214 : 214 213 : 213 250 : 212 251 : 211 252
       253 254 : 224 255
       210 209 : 209 206 : 206 234 : 234 256 : 256 257
       257 258 : 258 259 : 259 260 : 260 261 : 261 262 : 262 239
SLINES 250 212 : 251 249 : 249 211 : 252 253 : 254 224 : 255 210
IJSOL  0 0 1 SO
RULE   5 1
KNAME  150 157 1 1 FACE IN CENT B
       134 159 1 5 FACE IN RIGH B
#---------      139 159 1 5 FACE IN TOP B    (VANE2.PRF)
MESH
MERGE
ASSIGN TOLX=0.005
MERGE
ASSIGN TOLX=0.001
#---------- MESH 4 - CONVEX  BOTTOM  LEFT ------------------------
#--------- STATION 7 ---------------------------------------------
IJPOIN 731  1  1  3.121          24.          _Z=1.34     91    8 94
       732 23  1  3.121         -30.            1.34      91    8 94
       733 23  3  1.5805887     -30.          172.         8    8
IJPOIN 706 19  3    .170        -41.4802333    -.150      19    8 15 49
ASSIGN TOLX=.005705
IJPOIN 705 15  3 _r=.170       -131.4802333    -.150      19    8 49 65
IJPOIN 734 15  9 _x=.5         .868           -.150       15    8    65
IJPOIN 724 13  9 _x=.5         .868           -.150       15    8    65
IJPOIN 723 13 11 _x=.381       .868           -.150       15    7  8 65
ASSIGN TOLX=0.001
IJPOIN 735 13 15 _x=0.      _y=.868         _z=-.150      15    7    65
IJPOIN 704 11 15 _x=0.      _y=.868         _z=-.150      15    7    65
IJPOIN 736 11 21 _x=-.51    _y=.868         _z=-.150      15    7    65
IJPOIN 722  9 21 _x=-.51    _y=.868         _z=-.150      15    7    65
IJPOIN 703  9 23    .170       -131.4802333    -.150      16    7 46 65
IJPOIN 702  9 25    .170       -160.           -.150      16    7    46
IJPOIN 701  9 27 _R=.170 _THETA=138.5197667 _Z=-.150      16    7 15 46
       737  9 29   4.155          9.        2.66          91    7 93
IJPOIN 738  1 29   4.155         24.        2.66          91    7 93
ASSIGN TOLX=.006
IJPOIN 739  1 11   1.3     24.             150.3955773     7    7  8
ASSIGN TOLX=.001
IJPOIN 760  9 31   4.195          9.        2.663         91    7 95
       761  1 31   4.195         24.        2.663         91    7 95
#--------- STATION 8 ---------------------------------------------
IJPOIN 831  1  1  12.6536283     24.             75.      10   10 94
       832 23  1  12.6536283    -30.             75.      10   10 94
       833 23  3  12.75         -30.             75.      10   10
IJPOIN 806 19  3    .170        -41.4802333  -.425        19   10 15 49
ASSIGN TOLX=.005
IJPOIN 805 15  3 _r=.170       -131.4802333    -.425      19   10 49 65
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IJPOIN 834 15  9 _x=.5218596 1.143          -.170      15    9 10 65
IJPOIN 823 13  9 _x=.5218596 1.143          -.170      15    9 10 65
ASSIGN TOLX=0.001
IJPOIN 835 13 15 _x=0.     _y=1.143        _z=-.170    15    9    65
IJPOIN 804 11 15 _x=0.     _y=1.143        _z=-.170    15    9    65
       836 11 21 _x=-.6353931 1.143         -.170      15    9    65
       822  9 21 _x=-.6353931 1.143         -.170      15    9    65
IJPOIN 803  9 23    .170        -131.4802333    -.425  16    9    46
IJPOIN 802  9 25    .170        -160.           -.425  16    9    46
IJPOIN 801  9 27 _R=.170 _THETA=138.5197667 _Z=-.425   16    9 15 46
       838  9 29   4.155           9.          2.543   91    9 93 96
IJPOIN 839  1 29   4.155          24.          2.543   91    9 93 96
IJPOIN 840  1 21 _R=5.5652664     24.         45.       9    9
       841  1  9   13.1076135     24.         75.      10    9 10
       860  9 31   4.195           9.          2.543   91    95 96
       861  1 31   4.195          24.          2.543   91    95 96
#------------------------------------------------------------------
SINTER 731 732 : 732 733 : 733 706 : 706 705 : 705 734 : 724 723
       723 735 : 704 736
       722 703 : 703 702 : 702 701 : 701 737 : 737 738 : 738 739
       739 731 : 737 760 : 760 761 : 761 738
SLINES 734 724 : 735 704 : 736 722
#------------------------------------------------------------------
IJGRID 1
SINTER 831 832 : 832 833 : 833 806 : 806 805 : 805 834 : 823 835
       804 836
       822 803 : 803 802 : 802 801 : 801 838 : 838 839 : 839 840
       840 841 : 841 831 : 838 860 : 860 861 : 861 839
SLINES 834 823 : 835 804 : 836 822
IJSOL  0 0 1 SO
RULE   5 1
KNAME  834 840 5 5 FACE OUT CENT A
       831 861 1 5 FACE OUT LEFT A
       832 833 1 5 FACE OUT RIGH A
#----------        838 839 1 5 FACE OUT TOP A   (VANE.PRF)
MESH
MERGE
ASSIGN TOLX=0.005
MERGE
ASSIGN TOLX=0.001
#---------- MESH 5 - CONVEX  BOTTOM  RIGHT -----------------------------
#--------- STATION 7 ------------------------------------
IJPOIN 737  1 27   4.155             9.          2.663  91     7 93
IJPOIN 701  1 25 _R=.170 _THETA=138.5197667 _Z=-.150  16     7 15 46
ASSIGN TOLX=0.005
IJPOIN 714  3 25   2.144          70.6675        -.150  17     7 46 47
IJPOIN 713  5 25   2.144          68.8300281     -.150  17     7    47
ASSIGN TOLX=0.001
IJPOIN 750  5 21   2.144          59.            -.150  17     7    47
IJPOIN 728  7 21   2.144          59.            -.150  17     7    47
IJPOIN 751  7 19   2.144          54.5           -.150  17     7    47
IJPOIN 727  9 19   2.144          54.5           -.150  17     7    47
IJPOIN 752  9 17   2.144          49.8589617     -.150  17     7 47 48
IJPOIN 712 11 17   2.144          49.8589617     -.150  17     7 47 48
IJPOIN 753 11 11   3.419          40.            -.150  18     7    48
IJPOIN 726 13 11   3.419          40.            -.150  18     7    48
ASSIGN TOLX=0.0058
IJPOIN 711 13  9   3.419          35.25     -.150  18     7  8 48
ASSIGN TOLX=0.001
IJPOIN 754 13  7   3.419          34.            -.150  18     8 48
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IJPOIN 725 15  7   3.419        34.            -.150  18     8 48
IJPOIN 710 15  5    .170        30.8790069     -.150  19     8 48 49
IJPOIN 709 15  3    .170        -5.5           -.150  19     8    49
IJPOIN 706 15  1    .170       -41.4802333     -.150  19     8 15 49
       733 19  1  1.5805887    -30.           172.     8     8
ASSIGN TOLX=0.006
IJPOIN 755 19  9   1.3         -30.      150.3955773   7     7  8
ASSIGN TOLX=0.001
IJPOIN 756 19 27   4.155       -30.            2.66   91     7 93
IJPOIN 757  5 27   4.155         5.            2.66   91     7 93
IJPOIN 758  3 27   4.155         7.            2.66   91     7 93
       762 19 29   4.195       -30.            2.663  91     7 95
       763  5 29   4.195         5.            2.663  91     7 95
       764  3 29   4.195         7.            2.663  91     7 95
       760  1 29   4.195         9.            2.663  91     7 95
#--------- STATION 8 ------------------------------------
IJPOIN 838  1 27   4.155         9.        2.543      91   9 93 96
IJPOIN 801  1 25    .170     138.5197667   -.425  16     9 15 46
IJPOIN 814  3 25    .11       90.          -.425  16     9
IJPOIN 813  5 25   2.144      68.8300281   -.425  17     9    47
       850  5 21   2.144      58.          -.425  17     9    47
       826  7 21   2.144      58.          -.425  17     9    47
       851  7 19   2.144      52.7420319   -.425  17     9    47
       825  9 19   2.144      52.7420319   -.425  17     9    47
IJPOIN 852  9 17   2.144      49.8589617   -.425  17     9 47 48
IJPOIN 812 11 17   2.144      49.8589617   -.425  17     9 47 48
       853 11 11   3.419      41.          -.425  18     9    48
       824 13 11   3.419      41.          -.425  18     9    48
IJPOIN 854 13  7   3.419      33.5646343   -.425  18    10  9 48
IJPOIN 811 15  7   3.419      33.5646343   -.425  18    10  9 48
IJPOIN 810 15  5    .170      30.8790069   -.425  19    10 48 49
IJPOIN 809 15  3    .170      -5.5         -.425  19    10    49
IJPOIN 806 15  1    .170     -41.4802333   -.425  19    10 15 49
       833 19  1  12.75      -30.         75.     10    10
       855 19  7  13.1076135    -30.      75.     10     9 10
IJPOIN 856 19 19 _R=5.5652664   -30.      45.      9     9
IJPOIN 857 19 27 ¯ 4.155        -30.      2.543   91     9 93 96
IJPOIN 858  5 27   4.155          5.      2.543   91     9 93 96
IJPOIN 859  3 27   4.155          7.      2.543   91     9 93 96
       860  1 29   4.195          9.      2.543   91    95 96
       862 19 29   4.195        -30.      2.543   91    95 96
       863  5 29   4.195          5.      2.543   91    95 96
       864  3 29   4.195          7.      2.543   91    95 96
#------------------------------------------------------------------
SINTER 737 701 : 701 714 : 714 713 : 713 750 : 728 751 : 727 752
       712 753 : 726 711 : 711 754 : 725 710 : 710 709 : 709 706
       706 733 : 733 755 : 755 756 : 756 757 : 757 758 : 758 737
       756 762 : 762 763 : 763 764 : 764 760 : 760 737
SLINES 750 728 : 751 727 : 752 712 : 753 726 : 754 725
#------------------------------------------------------------------
IJGRID 1
SINTER 838 801 : 801 814 : 814 813 : 813 850 : 826 851 : 825 852
       812 853 : 824 854 : 811 810 : 810 809 : 809 806 : 806 833
       833 855 : 855 856 : 856 857 : 857 858 : 858 859 : 859 838
       857 862 : 862 863 : 863 864 : 864 860 : 860 838
SLINES 850 826 : 851 825 : 852 812 : 853 824 : 854 811
IJSOL  0 0 1 SO
RULE   5 1
KNAME  851 855 5 5 FACE OUT CENT B
       833 862 1 5 FACE OUT RIGH B
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#----------------        838 857 1 5 FACE OUT TOP B    (VANE.PRF)
MESH
MERGE
ASSIGN TOLX=0.005
MERGE
ASSIGN TOLX=0.001
#------   MESH 6 TORUS INNER RING  -----------------------------------
#------   TORUS STATION 3 AT 0 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   101      1    5    3.525998    0.0     3.867997    91   3 90
          102      7    5    3.690646    0.0     4.143754    91
          107      1    1    3.563346    0.0     3.814658    91   1 90
          106      7    1    3.741757    0.0     4.119106    91
          108      7    3    3.716223    0.0     4.131503    91
          116     55    3    4.279954    0.0     2.590498    91
          110     55    1    4.290326    0.0     2.636950    91
          109     59    1    4.195000    0.0     2.662999    91   7 95
          114     55    5    4.269582    0.0     2.544046    91
          115     59    5    4.195000    0.0     2.554202    91  95 96
#VARYING POINTS
IJPOIN    103     13    5    3.881081    0.0     4.792418    91
          104     13    3    3.905653    0.0     4.787814    91
          105     13    1    3.930226    0.0     4.783211    91
          111     49    1    4.717591    0.0     2.345176    91
          112     49    3    4.704024    0.0     2.324177    91
          113     49    5    4.690458    0.0     2.303178    91
          117     33    3    8.649978    0.0     4.182926    91
          118      0    0    6.240000    0.0     4.182997    91
#------   TORUS STATION 3.1 AT 7.5 DEGREE   --------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   201      1    5    3.525998    -7.5     3.867997    91   3 90
          202      7    5    3.690646    -7.5     4.143754    91
          207      1    1    3.563346    -7.5     3.814658    91   1 90
          206      7    1    3.741757    -7.5     4.119106    91
          208      7    3    3.716223    -7.5     4.131503    91
          216     55    3    4.279954    -7.5     2.590498    91
          210     55    1    4.290326    -7.5     2.636950    91
          209     59    1    4.195000    -7.5     2.662999    91   7 95
          214     55    5    4.269582    -7.5     2.544046    91
          215     59    5    4.195000    -7.5     2.554202    91  95 96
#VARYING POINTS
IJPOIN    203     13    5    3.8806591   -7.5     4.7860231   91
          204     13    3    3.9052143   -7.5     4.7813334   91
          205     13    1    3.9297707   -7.5     4.7766447   91
          211     49    1    4.7158003   -7.5     2.3468049   91
          212     49    3    4.7022295   -7.5     2.3258080   91
          213     49    5    4.6886601   -7.5     2.3048112   91
          217     33    3    8.5976315   -7.5     4.1729436   91
          218      0    0    6.2124996   -7.5     4.1729970   91
#------   TORUS STATION 3.2 AT 15 DEGREE   ---------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   301      1    5    3.525998    -15.0    3.867997    91   3 90
          302      7    5    3.690646    -15.0    4.143754    91
          307      1    1    3.563346    -15.0    3.814658    91   1 90
          306      7    1    3.741757    -15.0    4.119106    91
          308      7    3    3.716223    -15.0    4.131503    91
          316     55    3    4.279954    -15.0    2.590498    91
          310     55    1    4.290326    -15.0    2.636950    91
          309     59    1    4.195000    -15.0    2.662999    91   7 95
          314     55    5    4.269582    -15.0    2.544046    91
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          315      59    5    4.195000    -15.0      2.554202     91 95 96
#VARYING POINTS
IJPOIN    303      13    5    3.8802371   -15.0      4.7796288    91
          304      13    3    3.9047756   -15.0      4.7748528    91
          305      13    1    3.9293151   -15.0      4.7700782    91
          311      49    1    4.7140098   -15.0      2.3484335    91
          312      49    3    4.7004356   -15.0      2.3274391    91
          313      49    5    4.6868625   -15.0      2.3064446    91
          317      33    3    8.5452862   -15.0      4.1629610    91
          318       0    0    6.1849990   -15.0      4.1629968    91
#------   TORUS STATION 3.3 AT 17 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   401       1    5    3.525998    -17.0      3.867997     91  3 90
          402       7    5    3.690646    -17.0      4.143754     91
          407       1    1    3.563346    -17.0      3.814658     91  1 90
          406       7    1    3.741757    -17.0      4.119106     91
          408       7    3    3.716223    -17.0      4.131503     91
          416      55    3    4.279954    -17.0      2.590498     91
          410      55    1    4.290326    -17.0      2.636950     91
          409      59    1    4.195000    -17.0      2.662999     91  7 95
          414      55    5    4.269582    -17.0      2.544046     91
          415      59    5    4.195000    -17.0      2.554202     91 95 96
#VARYING POINTS
IJPOIN    403      13    5    3.8801246   -17.0      4.7779231    91
          404      13    3    3.9046586   -17.0      4.7731242    91
          405      13    1    3.9291937   -17.0      4.7683272    91
          411      49    1    4.7135320   -17.0      2.3488679    91
          412      49    3    4.6999569   -17.0      2.3278739    91
          413      49    5    4.6863832   -17.0      2.3068800    91
          417      33    3    8.5313272   -17.0      4.1602988    91
          418       0    0    6.1776657   -17.0      4.1603298    91
#------   TORUS STATION 3.4 AT 19 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   501       1    5    3.525998    -19.0      3.867997     91  3 90
          502       7    5    3.690646    -19.0      4.143754     91
          507       1    1    3.563346    -19.0      3.814658     91  1 90
          506       7    1    3.741757    -19.0      4.119106     91
          508       7    3    3.716223    -19.0      4.131503     91
          516      55    3    4.279954    -19.0      2.590498     91
          510      55    1    4.290326    -19.0      2.636950     91
          509      59    1    4.195000    -19.0      2.662999     91  7 95
          514      55    5    4.269582    -19.0      2.544046     91
          515      59    5    4.195000    -19.0      2.554202     91 95 96
#VARYING POINTS
IJPOIN    503      13    5    3.8800120   -19.0      4.7762179    91
          504      13    3    3.9045415   -19.0      4.7713962    91
          505      13    1    3.9290721   -19.0      4.7665758    91
          511      49    1    4.7130547   -19.0      2.3493021    91
          512      49    3    4.6994786   -19.0      2.3283091    91
          513      49    5    4.6859035   -19.0      2.3073156    91
          517      33    3    8.5173683   -19.0      4.1576371    91
          518       0    0    6.1703320   -19.0      4.1576629    91
#------   TORUS STATION 3.5 AT 24 DEGREE   ---------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT   601       1    5    3.525998    -24.0      3.867997     91  3 90
          602       7    5    3.690646    -24.0      4.143754     91
          607       1    1    3.563346    -24.0      3.814658     91  1 90
          606       7    1    3.741757    -24.0      4.119106     91
          608       7    3    3.716223    -24.0      4.131503     91
          616      55    3    4.279954    -24.0      2.590498     91
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         610      55    1    4.290326     -24.0      2.636950     91
         609      59    1    4.195000     -24.0      2.662999     91  7 95
         614      55    5    4.269582     -24.0      2.544046     91
         615      59    5    4.195000     -24.0      2.554202     91 95 96
#VARYING POINTS
IJPOIN   603      13    5    3.8797307    -24.0      4.7719550    91
         604      13    3    3.9042490    -24.0      4.7670755    91
         605      13    1    3.9287684    -24.0      4.7621984    91
         611      49    1    4.7118607    -24.0      2.3503881    91
         612      49    3    4.6982822    -24.0      2.3293962    91
         613      49    5    4.6847053    -24.0      2.3084044    91
         617      33    3    8.4824705    -24.0      4.1509819    91
         618       0    0    6.1519985    -24.0      4.1509962    91
#------  TORUS STATION 3.6 AT 29 DEGREE   ----------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT  701       1    5    3.525998     -29.0      3.867997     91  3 90
         702       7    5    3.690646     -29.0      4.143754     91
         707       1    1    3.563346     -29.0      3.814658     91  1 90
         706       7    1    3.741757     -29.0      4.119106     91
         708       7    3    3.716223     -29.0      4.131503     91
         716      55    3    4.279954     -29.0      2.590498     91
         710      55    1    4.290326     -29.0      2.636950     91
         709      59    1    4.195000     -29.0      2.662999     91  7 95
         714      55    5    4.269582     -29.0      2.544046     91
         715      59    5    4.195000     -29.0      2.554202     91 95 96
#VARYING POINTS
IJPOIN   703      13    5    3.8794494    -29.0      4.7676916    91
         704      13    3    3.9039564    -29.0      4.7627549    91
         705      13    1    3.9284649    -29.0      4.7578206    91
         711      49    1    4.7106671    -29.0      2.3514738    91
         712      49    3    4.6970863    -29.0      2.3304837    91
         713      49    5    4.6835070    -29.0      2.3094933    91
         717      33    3    8.4475737    -29.0      4.1443267    91
         718       0    0    6.1336651    -29.0      4.1443291    91
#------  TORUS STATION 5.1 AT 34 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT  801       1    5    3.525998      -34.0      3.867997     91  3 90
         802       7    5    3.690646      -34.0      4.143754     91
         807       1    1    3.563346      -34.0      3.814658     91  1 90
         806       7    1    3.741757      -34.0      4.119106     91
         808       7    3    3.716223      -34.0      4.131503     91
         816      55    3    4.279954      -34.0      2.590498     91
         810      55    1    4.290326      -34.0      2.636950     91
         809      59    1    4.195000      -34.0      2.662999     91  7 95
         814      55    5    4.269582      -34.0      2.544046     91
         815      59    5    4.195000      -34.0      2.554202     91 95 96
#VARYING POINTS
IJPOIN   803      13    5    3.8791013    -34.0      4.7621150    91
         804      13    3    3.9035928    -34.0      4.7571039    91
         805      13    1    3.9280858    -34.0      4.7520952    91
         811      49    1    4.7087231    -34.0      2.3520501    91
         812      49    3    4.6950526    -34.0      2.3311200    91
         813      49    5    4.6813831    -34.0      2.3101897    91
         817      33    3    8.4076223    -34.0      4.1356626    91
         818       0    0    6.1126652    -34.0      4.1356626    91
#------  TORUS STATION 5.2 AT 39 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT  901       1    5    3.525998     -39.0      3.867997     91  3 90
         902       7    5    3.690646     -39.0      4.143754     91
         907       1    1    3.563346     -39.0      3.814658     91  1 90
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         906        7    1    3.741757    -39.0      4.119106    91
         908        7    3    3.716223    -39.0      4.131503    91
         916       55    3    4.279954    -39.0      2.590498    91
         910       55    1    4.290326    -39.0      2.636950    91
         909       59    1    4.195000    -39.0      2.662999    91   7 95
         914       55    5    4.269582    -39.0      2.544046    91
         915       59    5    4.195000    -39.0      2.554202    91  95 96
#VARYING POINTS
IJPOIN   903       13    5    3.8787367  -39.0     4.7562099   91
         904       13    3    3.9032116  -39.0     4.7511201   91
         905       13    1    3.9276876  -39.0     4.7460327   91
         911       49    1    4.7065916  -39.0     2.3524990   91
         912       49    3    4.6928096  -39.0     2.3316436   91
         913       49    5    4.6790285  -39.0     2.3107884   91
         917       33    3    8.3664074  -39.0     4.1264963   91
         918        0    0    6.0909986  -39.0     4.1264963   91
#------  TORUS STATION 5.3 AT 44 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT 1001        1    5    3.525998    -44.0      3.867997    91   3 90
        1002        7    5    3.690646    -44.0      4.143754    91
        1007        1    1    3.563346    -44.0      3.814658    91   1 90
        1006        7    1    3.741757    -44.0      4.119106    91
        1008        7    3    3.716223    -44.0      4.131503    91
        1016       55    3    4.279954    -44.0      2.590498    91
        1010       55    1    4.290326    -44.0      2.636950    91
        1009       59    1    4.195000    -44.0      2.662999    91   7 95
        1014       55    5    4.269582    -44.0      2.544046    91
        1015       59    5    4.195000    -44.0      2.554202    91  95 96
#VARYING POINTS
IJPOIN  1003       13    5    3.8783720  -44.0     4.7503052   91
        1004       13    3    3.9028301  -44.0     4.7451367   91
        1005       13    1    3.9272897  -44.0     4.7399702   91
        1011       49    1    4.7044601  -44.0     2.3529477   91
        1012       49    3    4.6905665  -44.0     2.3321674   91
        1013       49    5    4.6766739  -44.0     2.3113868   91
        1017       33    3    8.3251934  -44.0     4.1173301   91
        1018        0    0    6.0693326  -44.0     4.1173301   91
#------  TORUS STATION 5.4 AT 49 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
IJPOINT 1101        1    5    3.525998    -49.0      3.867997    91   3 90
        1102        7    5    3.690646    -49.0      4.143754    91
        1107        1    1    3.563346    -49.0      3.814658    91   1 90
        1106        7    1    3.741757    -49.0      4.119106    91
        1108        7    3    3.716223    -49.0      4.131503    91
        1116       55    3    4.279954    -49.0      2.590498    91
        1110       55    1    4.290326    -49.0      2.636950    91
        1109       59    1    4.195000    -49.0      2.662999    91   7 95
        1114       55    5    4.269582    -49.0      2.544046    91
        1115       59    5    4.195000    -49.0      2.554202    91  95 96
#VARYING POINTS
IJPOIN  1103       13    5    3.8780072  -49.0     4.7444000   91
        1104       13    3    3.9024489  -49.0     4.7391529   91
        1105       13    1    3.9268918  -49.0     4.7339077   91
        1111       49    1    4.7023282  -49.0     2.3533967   91
        1112       49    3    4.6883235  -49.0     2.3326910   91
        1113       49    5    4.6743193  -49.0     2.3119853   91
        1117       33    3    8.2839785  -49.0     4.1081638   91
        1118        0    0    6.0476661  -49.0     4.1081638   91
#------  TORUS STATION 5.5 AT 54 DEGREE   ------------------------------
#FIXED POINTS (EXCEPT FOR THETA)
```

```
IJPOINT  1201      1    5    3.525998      -54.0      3.867997     91   3 90
         1202      7    5    3.690646      -54.0      4.143754     91
         1207      1    1    3.563346      -54.0      3.814658     91   1 90
         1206      7    1    3.741757      -54.0      4.119106     91
         1208      7    3    3.716223      -54.0      4.131503     91
         1216     55    3    4.279954      -54.0      2.590498     91
         1210     55    1    4.290326      -54.0      2.636950     91
         1209     59    1    4.195000      -54.0      2.662999     91   7 95
         1214     55    5    4.269582      -54.0      2.544046     91
         1215     59    5    4.195000      -54.0      2.554202     91  95 96
#VARYING POINTS
         1203     13    5    3.8776426   -54.0    4.7384949    91
         1204     13    3    3.9020674   -54.0    4.7331691    91
         1205     13    1    3.9264936   -54.0    4.7278452    91
         1211     49    1    4.7001967   -54.0    2.3538454    91
         1212     49    3    4.6860809   -54.0    2.3332145    91
         1213     49    5    4.6719646   -54.0    2.3125839    91
         1217     33    3    8.2427645   -54.0    4.0989976    91
         1218      0    0    6.0259995   -54.0    4.0989976    91
#-------------------------------------------------------------------
SLINES  101 102 103 104 105 106 107 : 108 104
SINTER  107 101
#-------------------------------------------------------------------
IJGRID 1
SLINES  201 202 203 204 205 206 207 : 208 204
SINTER  207 201
#-------------------------------------------------------------------
IJGRID 2
SLINES  301 302 303 304 305 306 307 : 308 304
SINTER  307 301
#-------------------------------------------------------------------
IJGRID 3
SLINES  401 402 403 404 405 406 407 : 408 404
SINTER  407 401
#-------------------------------------------------------------------
IJGRID 4
SLINES  501 502 503 504 505 506 507 : 508 504
SINTER  507 501
#-------------------------------------------------------------------
IJGRID 5
SLINES  601 602 603 604 605 606 607 : 608 604
SINTER  607 601
#-------------------------------------------------------------------
IJGRID 6
SLINES  701 702 703 704 705 706 707 : 708 704
SINTER  707 701
#-------------------------------------------------------------------
IJGRID 7
SLINES  801 802 803 804 805 806 807 : 808 804
SINTER  807 801
#-------------------------------------------------------------------
IJGRID 8
SLINES  901 902 903 904 905 906 907 : 908 904
SINTER  907 901
#-------------------------------------------------------------------
IJGRID 9
SLINES  1001 1002 1003 1004 1005 1006 1007 : 1008 1004
SINTER  1007 1001
#-------------------------------------------------------------------
IJGRID 10
```

```
SLINES  1101 1102 1103 1104 1105 1106 1107 : 1108 1104
SINTER  1107 1101
#------------------------------------------------------------------------
IJGRID 11
SLINES  1201 1202 1203 1204 1205 1206 1207 : 1208 1204
SINTER  1207 1201 .
#------------------------------------------------------------------------
IJSOL   107 103 1 SO 0 TORU IN SOL
RULE  9 1 2
     13 3 4
     17 5 6
     21 7 8
     25 9 10
     27 11
KNAME 107 103 1 1 FACE TORU IN LARG
KNAME 1207 1203 27 27 FACE TORU IN SMAL
IJNAME 107 101 FACE AAAA
MESH 0 1
ROTATE 24. 3
MERGE
ASSIGN TOLX=0.005
MERGE
ASSIGN TOLX=0.001
#------   MESH 7 TORUS OUTER RING   ---------------------------------
SLINES  109 110 111 112 113 114 115 109 : 112 116
#------------------------------------------------------------------------
IJGRID 1
SLINES  209 210 211 212 213 214 215 209 : 212 216
#------------------------------------------------------------------------
IJGRID 2
SLINES  309 310 311 312 313 314 315 309 : 312 316
#------------------------------------------------------------------------
IJGRID 3
SLINES  409 410 411 412 413 414 415 409 : 412 416
#------------------------------------------------------------------------
IJGRID 4
SLINES  509 510 511 512 513 514 515 509 : 512 516
#------------------------------------------------------------------------
IJGRID 5
SLINES  609 610 611 612 613 614 615 609 : 612 616
#------------------------------------------------------------------------
IJGRID 6
SLINES  709 710 711 712 713 714 715 709 : 712 716
#------------------------------------------------------------------------
IJGRID 7
SLINES  809 810 811 812 813 814 815 809 : 812 816
#------------------------------------------------------------------------
IJGRID 8
SLINES  909 910 911 912 913 914 915 909 : 912 916
#------------------------------------------------------------------------
IJGRID 9
SLINES  1009 1010 1011 1012 1013 1014 1015 1009 : 1012 1016
#------------------------------------------------------------------------
IJGRID 10
SLINES  1109 1110 1111 1112 1113 1114 1115 1109 : 1112 1116
#------------------------------------------------------------------------
IJGRID 11
SLINES  1209 1210 1211 1212 1213 1214 1215 1209 : 1212 1216
#------------------------------------------------------------------------
IJSOL   111 115 1 SO 0 TORU OUT SOL
```

```
RULE  9 1 2
     13 3 4
     17 5 6
     21 7 8
     25 9 10
     27 11
KNAME 111 115 1 1 FACE TORU OUT LARG
KNAME 1211 1215 27 27 FACE TORU OUT SMAL
IJNAME 1209 1215 FACE BBBB
MESH 0 1
ROTATE 24. 3
MERGE
ASSIGN TOLX=0.005
MERGE
ASSIGN TOLX=0.001
#-------- MESH 8  TORUS SHELL -----------------------------------------
SLINES  103 104 105 : 111 112 113
CIRCLE  104 117 118 : 117 112 118
#---------------------------------------------------------------------
IJGRID 1
SLINES  203 204 205 : 211 212 213
CIRCLE  204 217 218 : 217 212 218
#---------------------------------------------------------------------
IJGRID 2
SLINES  303 304 305 : 311 312 313
CIRCLE  304 317 318 : 317 312 318
#---------------------------------------------------------------------
IJGRID 3
SLINES  403 404 405 : 411 412 413
CIRCLE  404 417 418 : 417 412 418
#---------------------------------------------------------------------
IJGRID 4
SLINES  503 504 505 : 511 512 513
CIRCLE  504 517 518 : 517 512 518
#---------------------------------------------------------------------
IJGRID 5
SLINES  603 604 605 : 611 612 613
CIRCLE  604 617 618 : 617 612 618
#---------------------------------------------------------------------
IJGRID 6
SLINES  703 704 705 : 711 712 713
CIRCLE  704 717 718 : 717 712 718
#---------------------------------------------------------------------
IJGRID 7
SLINES  803 804 805 : 811 812 813
CIRCLE  804 817 818 : 817 812 818
#---------------------------------------------------------------------
IJGRID 8
SLINES  903 904 905 : 911 912 913
CIRCLE  904 917 918 : 917 912 918
#---------------------------------------------------------------------
IJGRID 9
SLINES  1003 1004 1005 : 1011 1012 1013
CIRCLE  1004 1017 1018 : 1017 1012 1018
#---------------------------------------------------------------------
IJGRID 10
SLINES  1103 1104 1105 : 1111 1112 1113
CIRCLE  1104 1117 1118 : 1117 1112 1118
#---------------------------------------------------------------------
IJGRID 11
```

```
SLINES  1203 1204 1205 : 1211 1212 1213
CIRCLE  1204 1217 1218 : 1217 1212 1218
#-----------------------------------------------------------------
IJSHE   103 105 2M.05 2M0.0 1 SH 0 -1 0 0 TORU IN SHEL
IJSHE   111 113 2M.05 2M0.0 1 SH 0 -1 0 0 TORU OUT SHEL
IJSHE   104 112 2M.05 2M0.0 1 SH 0 -1 0 0 TORU TORO SHEL
RULE  9 1 2
     13 3 4
     17 5 6
     21 7 8
     25 9 10
     27 11
KNAME 104 112 1 1 FACE TORU SHEL LARG
KNAME 1204 1212 27 27 FACE TORU SHEL SMAL
MESH 0 0 1
ROTATE 24. 3
MERGE
SHLNOR
DOFLOO
FINISH
STOP
$DF6
$RUN DIAL$DIR:BAND
START -1
REGPS
NPRINT
BAND
STOP
$RUN DIAL$DIR:SETUP
START
SETUP
STOP
$RUN DIAL$DIR:UTILITY
START
BCDOUT/UNFO=VAX    8 MATL.EV
BCDOUT/UNFO=VAX    8 ELEM.EV
BCDOUT/UNFO=VAX    8 INTO.EV
BCDOUT/UNFO=VAX    8 X.NV
BCDOUT/UNFO=VAX    8 NORM.NV
BCDOUT/UNFO=VAX    8 SKEW.NV
BCDOUT/UNFO=VAX    8 ROT.NV
BCDOUT/UNFO=VAX    8 DOF.NV
BCDOUT/UNFO=VAX    8 SDF.NV
BCDOUT/UNFO=VAX    8 RDF.NV
BCDOUT/UNFO=VAX    8 IR.NV
BCDOUT/UNFO=VAX    8 IER.EV
BCDOUT/UNFO=VAX    8 LCS.NV
BCDOUT/UNFO=VAX    8 ILL.NV
BCDOUT/UNFO=VAX    8 NAME.NV
BCDOUT/UNFO=VAX    8 NAME.EV
BCDOUT/UNFO=VAX    8 NXC.RM.DIR
BCDOUT/UNFO=VAX    8 SYS.CRM
BCDOUT/UNFO=VAX    8 PCT.HED.MESH
BCDOUT/UNFO=VAX    8 MESH.HED 0 ?
BCDOUT/UNFO=VAX    8 PCT.HED.SETU
BCDOUT/UNFO=VAX    8 CON.RM.DIR
BCDOUT/UNFO=VAX    8 CON.CON 0 ?
BCDOUT/UNFO=VAX    8 HEAD.COM
BCDOUT/UNFO=VAX    8 IER.NV
STOP
```

```
JOB,JN=VANE42,T=1000,CL=DEFERRD,MFL=1500000,US=670535.
ACCOUNT,AC=3,UPW=.
FETCH,DN=FIL001,DF=TR,TEXT='DIAL$CRAY:FIL001.'.
FETCH,DN=FIL002,DF=TR,TEXT='HYBRID6.DB'.
FETCH,DN=SCOPE,DF=TR,TEXT='DIAL$CRAY:SCOPE.CEX'.
FETCH,DN=DOMAIN,DF=TR,TEXT='DIAL$CRAY:DOMAIN.CEX'.
FETCH,DN=MESH,DF=TR,TEXT='DIAL$CRAY:MESH.CEX'.
FETCH,DN=BAND,DF=TR,TEXT='DIAL$CRAY:BAND.CEX'.
FETCH,DN=SETUP,DF=TR,TEXT='DIAL$CRAY:SETUP.CEX'.
FETCH,DN=MATL,DF=TR,TEXT='DIAL$CRAY:MATL.CEX'.
FETCH,DN=LOAD,DF=TR,TEXT='DIAL$CRAY:LOAD.CEX'.
FETCH,DN=SOLVE,DF=TR,TEXT='DIAL$CRAY:SOLVE.CEX'.
FETCH,DN=UTILITY,DF=TR,TEXT='DIAL$CRAY:UTILITY.CEX'.
SCOPE.
DOMAIN.
RELEASE,DN=FIL002.
FETCH,DN=FIL010,DF=TR,TEXT='VANE2.FL2'.
MESH.
BAND.
SETUP.
MATL.
DOMAIN.
LOAD.
SOLVE.
UTILITY.
DISPOSE,DN=FT08,DF=BB,TEXT='VANE42.U08'.
BAD.
EXIT.
SAVE,DN=FIL002,PDN=VANE42,ID=SZETO,NA.
DISPOSE,DF=TR,DN=FIL002,TEXT='VANE42.FL2'.
/EOF
$RUN DIAL$DIR:SCOPE
START -1
#-------------------------------------------------------------------------
#   APPLIED DISPLACEMENT CONDITIONS FROM NEW GLOBAL MODEL AND NEW LOADING
#   CONDITION - HYBRID6.DB
#-------------------------------------------------------------------------
DSET D 0 1
STOP
$RUN DIAL$DIR:DOMAIN
START
#------------------------------------------------------------
#  DOMAIN VOLUME FROM MAIN MODEL
#------------------------------------------------------------
FILE SUB [4]SUB
#--------- INNER RING ELEMENTS AT LARGER TORUS SIDE ------------
MSET=1 COPY RANGE=1 48 1
MSET=1 INSE RANGE=4951 4962 1
#--------- INNER RING ELEMENTS AT SMALLER TORUS SIDE ------------
MSET=2 COPY RANGE=193 240 1
MSET=2 INSE RANGE=4999 5010 1
#--------- OUTER RING ELEMENTS AT LARGER TORUS SIDE ------------
MSET=3 COPY RANGE=1441 1472 1
MSET=3 INSE RANGE 5307 5316 1
#--------- OUTER RING ELEMENTS AT SMALLER TORUS SIDE ------------
MSET=4 COPY  RANGE=1761 1792 1
MSET=4 INSE RANGE=5347 5356 1
#--------- LARGER TORUS SHELL SIDE ------------
MSET=5 COPY RANGE=5613 5630 1
#--------- SMALLER TORUS SHELL SIDE ------------
```

```
MSET=6 COPY RANGE=5685 5702 1
#-------- INNER RING CENTER PORTION ----------------------------
MSET=7 COPY RANGE=49 192 1
#-------- OUTER RING CENTER PORTION ----------------------------
MSET=8 COPY RANGE=1521 1552 1
MSET=8 INSE RANGE=1601 1632 1
MSET=8 INSE RANGE=1681 1712 1
#------------------
#----------------- TEST AREA 1 --------------------
MSET=9 COPY RANGE=4999 5010 1
MSET=9 INSE ELEM=228 229 231 232 235 236 239 240
#----------------- TEST AREA 2 --------------------
MSET=10 COPY ELEM=1761T1766 1780T1784 5347T5356
#----------------- TEST AREA 3 --------------------
MSET=11 COPY ELEM=1451T1454 1465T1468
SUBMOD 1 0 MSET=9
SUBSCA 1 1 [4]SUB.RV.DIS1,0,1
       1 2 [4]SUB.RV.DIS1,0,2
       1 3 [4]SUB.RV.DIS1,0,3
       1 4 [4]SUB.RV.DIS1,0,4
       1 5 [4]SUB.RV.DIS1,0,5
       1 6 [4]SUB.RV.DIS1,0,6
SUBMOD 2 0 MSET=10
SUBSCA 2 1 [4]SUB.RV.DIS2,0,1
       2 2 [4]SUB.RV.DIS2,0,2
       2 3 [4]SUB.RV.DIS2,0,3
       2 4 [4]SUB.RV.DIS2,0,4
       2 5 [4]SUB.RV.DIS2,0,5
       2 6 [4]SUB.RV.DIS2,0,6
SUBMOD 3 0 MSET=11
SUBSCA 3 1 [4]SUB.RV.DIS3,0,1
       3 2 [4]SUB.RV.DIS3,0,2
       3 3 [4]SUB.RV.DIS3,0,3
       3 4 [4]SUB.RV.DIS3,0,4
       3 5 [4]SUB.RV.DIS3,0,5
       3 6 [4]SUB.RV.DIS3,0,6
SUBMOD 4 0 MSET=1 2 3 4 5 6 7 8
SUBSCA 4 1 [4]SUB.RV.DIS4,0,1
       4 2 [4]SUB.RV.DIS4,0,2
       4 3 [4]SUB.RV.DIS4,0,3
       4 4 [4]SUB.RV.DIS4,0,4
       4 5 [4]SUB.RV.DIS4,0,5
       4 6 [4]SUB.RV.DIS4,0,6
STOP
$RUN DIAL$DIR:MESH
CLEAR 200000
MAX/MXPO=999    10000 2500
ELTYPE  4 2 6
ASSIGN  IPAL=0
#--------- MESH 1 COPY FROM VANE.PRF MODEL ALL MESHES -----
MODEL [10]
ROTATE -114. 3
SHLNOR
DOFLOO
DOFNOR 2
FINISH
STOP
$RUN DIAL$DIR:BAND
START -1
REGPS
```

```
BAND
STOP
$RUN DIAL$DIR:SETUP
START
SETUP
STOP
$RUN DIAL$DIR:MATL
START
#------ MATERIAL Ti-5Al-2.5Sn (ELI) ---------------
MATISO 1 .155E+08 .35 .3E-06 0.
MATL
STOP
$RUN DIAL$DIR:DOMAIN
START
FILE SUB [4]SUB
ASSIGN TOLV=2.0
MSET=1 COPY ELEM=714 724 794 804 1253T1264
NSET=1 COPY MSET=1
NSET=1 MASK NAME=FACE
DOMAIN/CLO 1 1 NSET=1
ASSIGN TOLV=.001
INTER/CLEA 1 [4]SUB.RV.DIS1,0,1 11
           1 [4]SUB.RV.DIS1,0,2 12
           1 [4]SUB.RV.DIS1,0,3 13
           1 [4]SUB.RV.DIS1,0,4 14
           1 [4]SUB.RV.DIS1,0,5 15
           1 [4]SUB.RV.DIS1,0,6 16
ASSIGN TOLV=3.0
MSET=2 COPY ELEM=1023 1032 1041 1090 1099 1108 1385T1394
NSET=2 COPY MSET=2
NSET=2 MASK NAME=FACE
DOMAIN/CLO 2 2 NSET=2
ASSIGN TOLV=.001
INTER/CLEA 2 [4]SUB.RV.DIS2,0,1 21
           2 [4]SUB.RV.DIS2,0,2 22
           2 [4]SUB.RV.DIS2,0,3 23
           2 [4]SUB.RV.DIS2,0,4 24
           2 [4]SUB.RV.DIS2,0,5 25
           2 [4]SUB.RV.DIS2,0,6 26
ASSIGN TOLV=2.0
MSET=3 COPY ELEM=805 816 823 830 837 890 901 908 915 922
NSET=3 COPY MSET=3
NSET=3 MASK NAME=FACE
DOMAIN/CLO 3 3 NSET=3
ASSIGN TOLV=.001
INTER/CLEA 3 [4]SUB.RV.DIS3,0,1 31
           3 [4]SUB.RV.DIS3,0,2 32
           3 [4]SUB.RV.DIS3,0,3 33
           3 [4]SUB.RV.DIS3,0,4 34
           3 [4]SUB.RV.DIS3,0,5 35
           3 [4]SUB.RV.DIS3,0,6 36
ASSIGN TOLV=.5
NSET=4 COPY NAME=FACE
NSET=4 DELE NSET=1 2 3
DOMAIN/CLO 4 4 NSET=4
ASSIGN TOLV=.001
INTER/CLEA 4 [4]SUB.RV.DIS4,0,1 41
           4 [4]SUB.RV.DIS4,0,2 42
           4 [4]SUB.RV.DIS4,0,3 43
           4 [4]SUB.RV.DIS4,0,4 44
```

```
          4 [4]SUB.RV.DIS4,0,5 45
          4 [4]SUB.RV.DIS4,0,6 46
STOP
$RUN DIAL$DIR:LOAD
START -1
LCASE 1      # APPLIED DISPLACEMENTS ON THE BOUNDARY
#------------ TEST AREA 1 ------------------------------------
U/NQU=11 0 1 NSET=1
U/NQU=12 0 2 NSET=1
U/NQU=13 0 3 NSET=1
U/NQU=14 0 4 NSET=1
U/NQU=15 0 5 NSET=1
U/NQU=16 0 6 NSET=1
#------------ TEST AREA 2 ---------------------------------------
U/NQU=21 0 1 NSET=2
U/NQU=22 0 2 NSET=2
U/NQU=23 0 3 NSET=2
U/NQU=24 0 4 NSET=2
U/NQU=25 0 5 NSET=2
U/NQU=26 0 6 NSET=2
#----------- TEST AREA 3 ----------------------------------------
U/NQU=31 0 1 NSET=3
U/NQU=32 0 2 NSET=3
U/NQU=33 0 3 NSET=3
U/NQU=34 0 4 NSET=3
U/NQU=35 0 5 NSET=3
U/NQU=36 0 6 NSET=3
#-----------  ALL EXCEPT THE ABOVE 3 AREAS --------------------
U/NQU=41 0 1 NSET=4
U/NQU=42 0 2 NSET=4
U/NQU=43 0 3 NSET=4
U/NQU=44 0 4 NSET=4
U/NQU=45 0 5 NSET=4
U/NQU=46 0 6 NSET=4
LCASE 2       # UNIT PRESSURE ON SURFACES
PSURF -303. 1 6 RANGE=561 644  1   # INNER RING PRESSURE SURFACE LEFT
      -303. 1 6 RANGE=725 804  1   # INNER RING PRESSURE SURFACE RIGHT
      -303. 1 3 RANGE=805 889  1   # OUTER RING PRESSURE SURFACE LEFT
      -303. 1 3 RANGE=975 1041 1   # OUTER RING PRESSURE SURFACE RIGHT
      -303. 1 2 RANGE= 57   70 1  # INNER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE= 71   84 1  # INNER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE= 85   98 1  # INNER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE= 99  112 1  # INNER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE=113  126 1  # INNER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE=127  140 1  # INNER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE=141  154 1  # INNER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE=155  168 1  # INNER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE=309  322 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE=323  336 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE=337  350 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE=351  364 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE=365  378 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE=379  392 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 2 RANGE=393  406 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 1
      -303. 1 5 RANGE=407  420 1  # OUTER RING PRESSURE SURFACE FILLET SIDE 2
      -303. 1 1 RANGE=1109 1259 12  # INNER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1110 1260 12  # INNER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1111 1261 12  # INNER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1112 1262 12  # INNER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1113 1263 12  # INNER RING PRESSURE SURFACE TORUS SOLID
```


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```
      -303. 1 1 RANGE=1114 1264 12  # INNER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1265 1385 10  # OUTER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1266 1386 10  # OUTER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1267 1387 10  # OUTER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1268 1388 10  # OUTER RING PRESSURE SURFACE TORUS SOLID
      -303. 1 1 RANGE=1269 1389 10  # OUTER RING PRESSURE SURFACE TORUS SOLID
       303. 1 -1 RANGE=1447 1680 1  # TORUS SHELL INSIDE PRESSURE
      -208. 1 3 ELEM=11T14 26T28    # INNER RING NONPRESSURE SURFACE VANE
      -208. 1 3 RANGE=477 517 1     # INNER RING NONPRESSURE SURFACE LEFT
      -208. 1 3 RANGE=645 651 1     # INNER RING NONPRESSURE SURFACE RIGHT
      -208. 1 6 ELEM=459T462 474T476 # OUTER RING NONPRESSURE SURFACE VANE
      -208. 1 6 RANGE=890 921 1      # OUTER RING NONPRESSURE SURFACE LEFT
      -208. 1 6 RANGE=1042 1047 1    # OUTER RING NONPRESSURE SURFACE RIGHT
LOAD
STOP
$RUN DIAL$DIR:SOLVE
START -1
REMARK 'UNIT LOAD CASE 1 - APPLIED DISPLACEMENTS
LOADS 1,1.0
ASSIGN RK=0.
SAVE D
SAVE S
SAVE EF
FILE K [3]KE
FILE KI [3]KI
SOLVE
REMARK 'UNIT LOAD CASE 2 - UNIT PRESSURE
LOADS 2,1.0
MATRIX
ASSIGN RK=0.
SAVE D
SAVE S
SAVE EF
FILE K [3]KE
FILE KI [3]KI
SOLVE
STOP
$UTILITY3
START -1
BCDOUT/UNFO=VAX    8 MATL.EV
BCDOUT/UNFO=VAX    8 ELEM.EV
BCDOUT/UNFO=VAX    8 INTO.EV
BCDOUT/UNFO=VAX    8 X.NV
BCDOUT/UNFO=VAX    8 NORM.NV
BCDOUT/UNFO=VAX    8 SKEW.NV
BCDOUT/UNFO=VAX    8 ROT.NV
BCDOUT/UNFO=VAX    8 DOF.NV
BCDOUT/UNFO=VAX    8 SDF.NV
BCDOUT/UNFO=VAX    8 RDF.NV
BCDOUT/UNFO=VAX    8 IR.NV
BCDOUT/UNFO=VAX    8 IER.EV
BCDOUT/UNFO=VAX    8 LCS.NV
BCDOUT/UNFO=VAX    8 ILL.NV
BCDOUT/UNFO=VAX    8 NAME.NV
BCDOUT/UNFO=VAX    8 NAME.EV
BCDOUT/UNFO=VAX    8 NXC.RM.DIR
BCDOUT/UNFO=VAX    8 SYS.CRM
BCDOUT/UNFO=VAX    8 PCT.HED.MESH
BCDOUT/UNFO=VAX    8 MESH.HED 0 ?
BCDOUT/UNFO=VAX    8 PCT.HED.SETU
```

```
BCDOUT/UNFO=VAX     8 CON.RM.DIR
BCDOUT/UNFO=VAX     8 CON.CON O ?
BCDOUT/UNFO=VAX     8 HEAD.COM
BCDOUT/UNFO=VAX     8 IER.NV
BCDOUT/UNFO=VAX     8 D.SV,?,?
BCDOUT/UNFO=VAX     8 S.EIP,?,?
BCDOUT/UNFO=VAX     8 R.SRV,?,?
BCDOUT/UNFO=VAX     8 EF.SEV,?,?
BCDOUT/UNFO=VAX     8 UL.SV,?,?
BCDOUT/UNFO=VAX     8 UL.NV,?,?
BCDOUT/UNFO=VAX     8 UAD.SV,?,?
BCDOUT/UNFO=VAX     8 UAD.NV,?,?
BCDOUT/UNFO=VAX     8 UT.NV,?,?
BCDOUT/UNFO=VAX     8 UT.NV.ENVI,?,?
BCDOUT/UNFO=VAX     8 STLT.RM.DIR
STOP
$DEASSIGN FOR006
/EOF
```